Minireview Article

Robotics Intervention in Food Processing Industries: A mini review

Abstract

The food manufacturing industry plays a crucial strategic role in economies of all the nations. Small and medium-sized businesses make up the vast majority of this sector in developing countries like India, Brazil, South Africa etc., that is both diversified and fragmented. Large numbers of labourers are necessary for the success of manufacturing operations because of the predominantly manual nature of these tasks. Due to the advancement in powerful, precise and rapid robots such as Delta class of robot, automation has been able to advance upstream and downstream operations, and perform rapid pick-and-place operations of food products on the assembly lines. There is number of modern robotics systems employed in food industries right now, and they're mostly geared toward the high-volume, long workability and handling single-product line. These robots have proven especially useful in the food processing industry because of their ability to efficiently handle high throughputs of products while only carrying light payloads of around one to two kilogrammes. The shortage of labours due to young people leaving their nation for better job opportunities in developed countries, and also in pandemic like situation, this had opened the doors for utilize other options for laborious tasks in important sectors like food processing industry. If robots would be used at larger extent in food processing industry at full capacity, in addition to boosting output, it has the potential to safeguard food supplies in unprecedented circumstances as in COVID-19 like scenario and beyond.

Keywords: Automation, Food industry, Food safety, Robots.

1. Introduction

The term "robot" has typically been used to refer to a manipulator that possesses several degrees of freedom and the ability to be reprogrammed through the utilisation of a high-level language. Robots are able to carry out a wide variety of jobs because they are equipped with a wide array of tools and can run the required software. The robotic arm could have anywhere from three to seven axes and be configured in either a serial or parallel fashion. Each joint has the capability of being operated by a driving system that is either electric, hydraulic, or pneumatic, and is controlled by a computer. It is possible to operate the joints of the robot through the use of a central controller, which allows the robot to carry out a variety of different movements. An input/output unit or a serial/parallel communication line can be used to interface the controller with other devices or systems, such as a computer vision system. One of these other devices or systems could be a computer (Bouge *et al*., 2009). In addition to this, the main controller supplies a method for the operator and the programmer to interface with the system (Khan *et al*., 2018). When it comes to food processing, it is imperative that the robotic arm, its controller, and any ancillary devices be built to endure working environment as well as the during conditions operation. While cleaning, it is common practise to make use of high-pressured hot water as well as a variety of chemical agents. The design of the system ought to be compliant with all of the mandatory standards and regulations that apply to machinery used in food processing. This is a necessary prerequisite that is being taken into serious consideration by makers of robots right now. Some companies that specialise in the manufacture of robots are now selling adaptable automation systems for the food processing industry. The primary obstacle, on the other hand, is that such robots cannot yet be used in the jobs that are currently being carried out by the skilled labour force. Innovative end-effectors and sensors are required so that manufacturers can meet the challenges posed by a wide variety of jobs, as well as variations in the form, size, and characteristics of the goods. The more difficult or highly skilled tasks may be automated through the combination of these technologies and the implementation of intelligent software with some capacity for learning. It will be necessary to construct robots with a higher level of intelligence in order to automate the myriad of chores that we perform without much thought. A significant part is played by the decision regarding the end effector (grippers, cutting tools, etc.) as well as the capabilities of the sensing technology, along with the software and control techniques for the manipulator, when it comes to the items that have a greater variety. Although integration has the potential to result in workable solutions in practically every circumstance, its applications in food processing have not yet been fully explored.

2. Robotic Food industry

During the previous decade, robots established a very noteworthy presence in a variety of business sectors. According to the *world robotics-2021 (industrial robots)* published by the International Federation of Robotics, the number of robots that were deployed across the globe in 2010 was just 0.12 million; however, this figure has climbed to 0.38 million in 2020. Between 2014 and 2019, annual installation saw an average annual growth of 11 per cent. The number of installations had climbed to 0.42 million by the end of 2018, but in 2019 this number declined slightly due to economic disagreements between the United States and China; and decreasing demand in robot-intensive industries, such as the automotive and electrical/ electronic industries. The numbers shown in Figure 1 represent the annual installation of industrial robots across the world. Total 0.38 million industrial robots were sold all over the world in 2020, with 0.26 million of the sales occurring just in Asia. Approximately 68% of all newly installed robots in 2020 were located in Asia. Because of the need to handle large pieces of machinery and do precise work, the automotive industry is the sector that makes the most use of robots. The food and beverage business are the fifth largest in organized sectors that utilises robots in their operations. At the moment, approximately three per cent of all robots manufactured were intended for use in the food and beverage business.

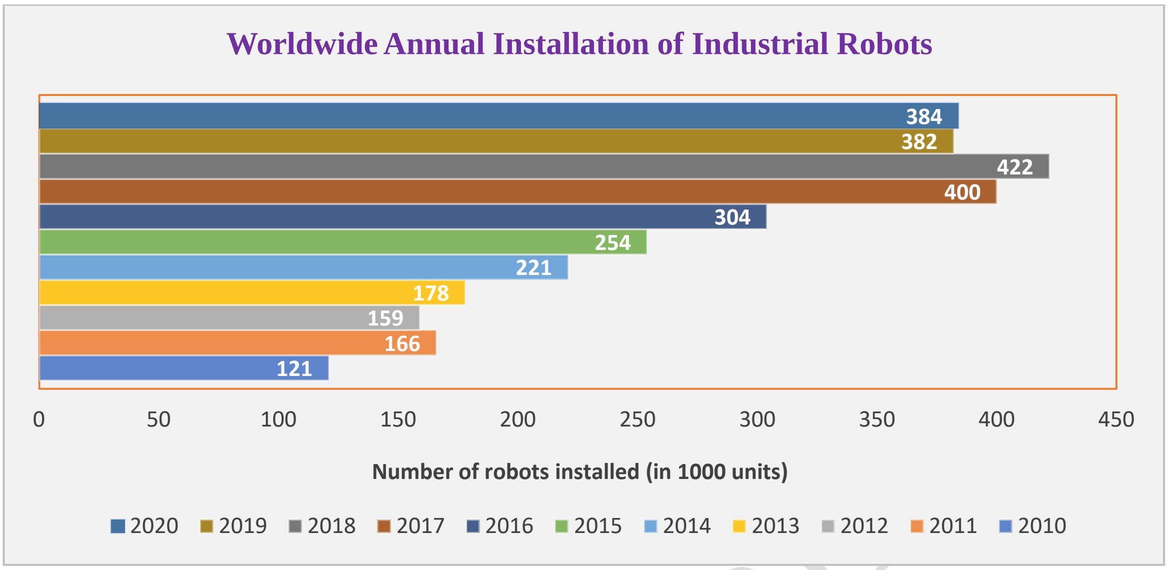

Figure 1. Worldwide annual installation of industrial robots, 2010-20 (Source: World Robotics 2021 (Industrial Robots))

Robots are having an increasingly significant impact on society for a number of reasons, the most important of which are the continued trend toward automation, the rapid advancement of technology, and the preparation for an industrial revolution. 4.0. South Korea, Singapore, Japan and Germany are the countries with the highest 'robot density,' which is defined as the number of robots in use per 10,000 employees. These countries respectively have 932, 605, 390 and 371 robots in their workplaces.

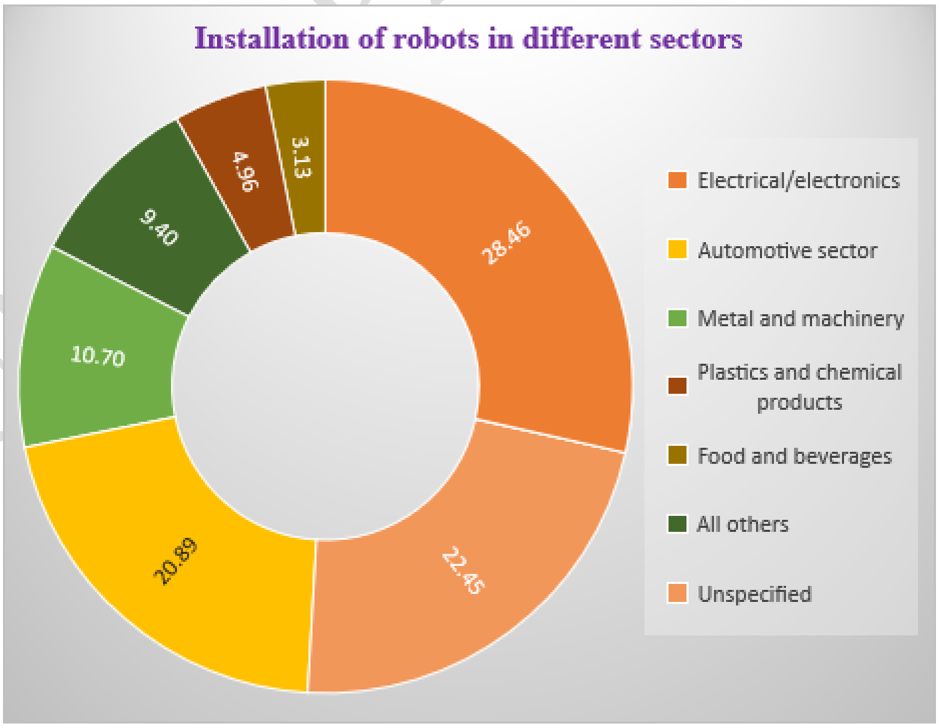

Figure 2. Share of robots in different sectors across the world in 2020

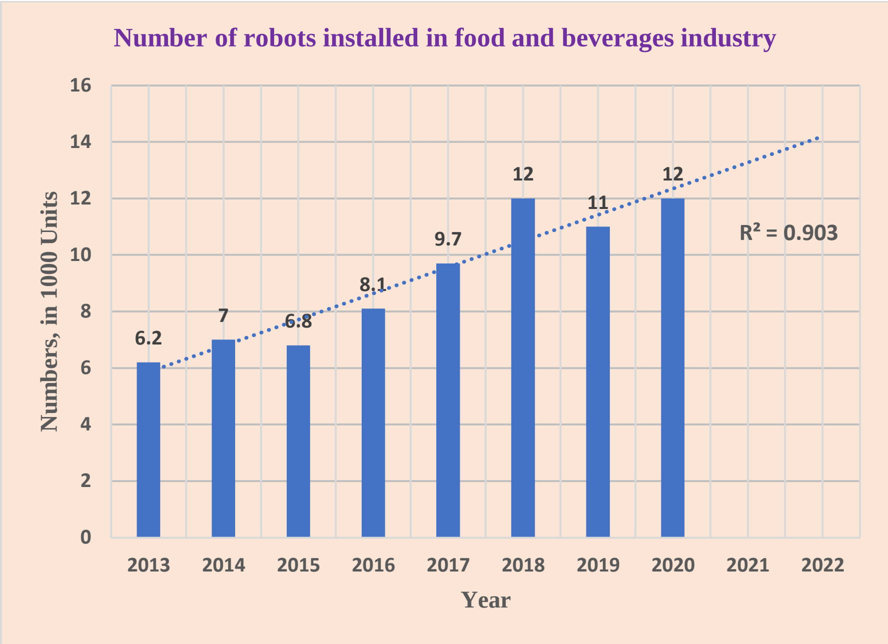

Figure 3. Worldwide number of robots installed in food and beverages industry in 2020

In the 1990s, the bakery business witnessed the very first instance of a robot being used for direct food handling for the very first time. These robots were able to carry out straightforward operations such as select and place at a respectable pace of between 55 and 80 cycles per minute. The most automatized organised sector is electronics and electricals followed by automotive sector. Currently, food and beverages sector are fifth highly automized among the organized sectors and is growing at satisfactory rate. Approximately 22.45 per cent of installed robots were installed in unspecified sector. This offers a huge potential to grab the opportunity and utilized such robots in food and beverages industry (Figure 2). The Figure 3, indicate total number of robots installed in food and beverages industry every year and its future trend of installation of robot in sector. In 2020, around 0.12 million robots were installed in food and beverages industry which is expected to increase to the level of 0.14 million in 2022. Although meat, fish, and poultry make up a sizeable amount of the food that is consumed around the world, the production of these foods does not lend itself very well to the use of mechanised processes. The diversity and adaptability of the products, as well as concerns over hygiene, quality, and the safety of the consumer, as well as increasing challenges associated with the manual processes involved in food production, are the primary causes of the issues. It is desirable to advance robotics science because its influences are encouraging the advancement of robotics and automation in meat production facilities. This eliminates the possibility of human contact with the product and, more importantly, removes workers from potentially hazardous working conditions. In this industry, the use of robots is prevalent for a number of objectively beneficial reasons, including higher productivity, improved production control, and output uniformity.

3. Applications of Robots in food sector

Meat and its allied sector of food industry is one of the major sectors which required to minimize human intervention and improving automation to reduce human drudgery and hygiene working environment. As studies reveal that meat packing is one of the riskiest tasks in the meat processing industry, many types of problems must be handled in order to keep the best quality of texture and dimensions. Robots have been developed to respond to the different characteristics of animal carcasses using sensors, meticulously determining each carcass's proportions before putting it. Due to the removal of human workers from this dangerous and tedious operation, the robot can now chop meat accurately, quickly and with more precision. There is a need for automation of splitting because carcass splitting requires a lot of force and a human cannot continue to operate at the same pace and accuracy for an extended period of time. For the first time ever in meat processing, an automation system was used for splitting. Guire *et al.* (2010) has created a robotic cell for cutting ham bones and quartering cattle carcasses. Processing of meat requires repetitious, physically exhausting, and maintaining hygiene as well as quality control. This kind of robotic cell has a vision system that determines the cutting path, and force control sensors are used to keep the cutting blade's distance from the spinal cord constant (Caldwell, 2012). A vision system is built into the robotic arm, which is also intended to be used for cutting hocks from carcasses. The cutting tool is immersed in a hot water tank for sanitization following each cycle of splitting. These types of robots can pick up stunned chicken from a conveyor belt and shackle it when handling stunned poultry. They determine the bird's centre of gravity and position it in relation to the robot. This optical system can also tell if a bird is lying with its breast up or down. In bakery industry, the robots are utilised in the packaging process on the biscuit production line. One robot picks up the biscuits and places them in a blister tray; a second robot packs the blister tray into retail packs. These robots contain "Dual check safety" (DCS) software, which keeps them in the right position and speed in relation to the conveyor's speed and biscuits' orientation. Because they require less maintenance and have a longer lifespan (>1 million cycles), magnetic grippers are used to handle baking tins that have reached temperatures higher than 1200 °C. Robots are employed in cake production lines for icing, decoration, and slicing. A camera equipped with a computer vision system is available to create a three-dimensional (3D) map of the cake's surface, which may then be used by the computer to determine the robot's tracking path when applying frosting or icing. To prevent cake deformation, these robots accurately adjust the distance between the "Icing gun" and the cake's surface. Robots are equipped with an ultrasonic knife installed on a multi-axis robotic arm that can provide a complex motion profile to cut many things at once while synchronising with the conveyor's speed on pastry production line. When handling muffins, a gripper of the needle type that has a handling capability of 1300 muffins per minute is employed. At a rate of 120 picks per minute, vacuum cup-style grippes are employed to handle the baked bread from a moving baking pan. Such type of robots is also required in the grading of horticultural commodities. Several businesses are engaged in the automatic grading of fruits and vegetables. Grading is the process that divides horticultural produce into different grades and necessitates the knowledge and experience of an individual. A mechanism for automatic examination had been created by Kondo N. (2009). This fruit-grading robot can evaluate 9000 fruits each hour and can capture photographs of the top, bottom and sides of each fruit in 4.5 seconds per cycle. Based on Bernoulli's principle, Davis *et al*. (2008) created a gripper in the series for handling delicately sliced fruits and vegetables. The gripper enables lifting of objects with little to no contact at all, minimising risk of contamination and damage to delicate fruits. Surface moisture can also be removed using the airflow created by the robot over the object.

Despite the fact that robots have long been used in various aspects of the food supply chain, they have only lately improved to the point where they can fully automate the packing process (Iqbal *et al*, 2017). This entails a switch to robotics for all of a facility's traditional contact points, including depalletizing, unpacking, and primary, secondary, and tertiary packaging. In quality control, this is very clear that robot should be provided with capability to see i.e., Machine vision system (Wilson, 2010). For instance, inspecting incoming materials before filling and after the filling process was historically performed manually.

However, with robotics, this role can be managed automatically in-line, with bottles being examined as they are filled. It includes handling unpackaged food items like cheese, meat, and poultry as well as bottles, trays, cartons, and other containers for food and drink. In reality, compared to humans, robots are capable of carrying out their tasks with higher accuracy and precision and in less time. These kinds of mechanic robots are utilized in storage, godowns and super markets. The facilities of Autonomous guided vehicles that can carry items on their top, tow objects behind them in trailers, or both are employed in warehouses. A select handful of these vehicles also have grippers to hold the stuff. Such robots have navigation systems so they may complete their tasks efficiently, quickly, and precisely without running into other robots or getting into the way of their work. Because mobile robots have trouble reacting to unanticipated disturbance, they are typically deployed in highly regulated situations like production lines. A universal gripper was created by Balaji *et al.* 2021 and may be used for a variety of objects, independent of their shapes. It can also be helpful in a number of food processing applications.

4. Robotics Aspects in the food processing industry:

Ensuring food safety and preventing contamination: Food-borne illnesses, which have a high morbidity and mortality rate due to tainted food and water, are a major problem around the world. Automation in the food industry can significantly reduce it by using methods like sanitation and controlled working conditions to prevent product contamination. Robotics-enabled automation can keep the processing line's hygiene up to par, as well as the hygiene of the robots themselves. With all food safety precautions, working in a closed environment is also possible for robots. With this benefit, food contamination can be considerably reduced (Haidegger *et al*., 2019). *Decision-making capacity*: The programmable language, which is simple to learn and can imitate the human brain, is used to fully operate the robots. Robots' ability to make decisions can fix the issue if the rapid change happened during an in-line process. Robots are less prone to error than humans because of their precise functioning methods. Robots with such properties can reduce damaged produce and losses in production. *Increase the production rate*: A single person may work continuously for 8 hours; over the time, this may limit the output of processed foods. A single robot can, however, do several activities that would take multiple people to complete with more accuracy and quickly than a human. Which helps in keeping the supply and demand chains moving smoothly. *Increased automation*: As a result of recent trends, the food and beverage industries are becoming increasingly mechanised. Traditional methods are ineffective in meeting the need for customised and intelligently packaged food when compared to the availability of advanced industrial and service robots. *Reducing carbon footprint*: In order to curtail down the carbon footprint, every year more sophisticated robots are being made. Because they use less energy during production and also, they lower overall energy consumption on production line. Higher precision merely results in fewer unwanted rejection and prevent production of inferior products. Additionally, this has a favourable effect on the ratio of resources input to output. *Secure supply chain*: The Covid-19 has exposed the industrial facilities' hidden flaws. Around 50 per cent of the workforce was still not permitted to work in industries after the lockdown lifted in many manufacturing hubs in various countries. Due to a total reliance on human labour, productivity in these industries had been impeded. *Heavy and tedious tasks*: The robots demonstrate their good faith with the modern development of collaborative robots and specialised grippers in order to avoid the drudgery and keep the ability to complete the boring activity.

5. Conclusions

Although new applications of robots are emerging, but in food industry till now they were being used largely for packaging and palletization tasks. The use of robotics in the food business in near future is getting both interesting and exciting which is one of the reasons that robotics is seeing higher degree of advancements. They can perform tasks where human workers would not be comfortable, and where consistency and steady strength are necessary, such as in slaughterhouses where the temperature is around 50 °C and same level of strength is required to perform task over prolong period. The grippers that directly comes in touch with food are constructed of high-grade aluminium, nickel-plated metals, or food grade stainless steel. These materials are simple to clean with high pressure water and prevent contamination while handling food products. Robotic intervention with such silent features makes sure the safety and security of the food product being processed. By keeping all factor in mind, we can assume that "self-operated machines" (Robots) can aid in boosting production and productivity in the food processing industries. In developing countries like India, operators control the operations of the machine, which hinders its ability to perform operation efficiently. Such robots can also be used to create reports from the saved data of processed food to keep the record. The foremost thing needs to ensure is that robots must be designed in such a way that they can be set up in order to work in close proximity of manual operation workers while maintaining a high level of safety.

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