INDUSTRIAL CROPS AND PRODUCTS ENGINEERING

Abstract

Industrial crops and product engineering focused on the cultivation, processing, utilization, production of industrial crops and it raw materials which are used commercially. There are so many important applications of industrial crops like biofuels production, textiles, rubber, papers etc. Industrial crops also manage the sustainability of earth and energies also. Industrial crops are non-food crops, these crops are cultivated mostly for the industrial products and there are so many industrial crops like cotton, corn, sugarcane, jute, rubber plant, etc. There so many technologies used for the cultivation or speedy production of crops, now days there are so many modern technologies are used for increasing the quantity and quality of the crops plant. So that industries can produce more and more good and raw materials. Product engineering was a field in which so many technologies and machineries were used in industries for the production, manufacture, storage and supplying of the raw materials, which are extracted from the different industrial crops. Technologies like robotics, refining, designing, post harvesting and so on, many technologies were utilized for the raw material extraction. Now a days AI, which was more advanced and fast technology, played crucial role in designing and manufacturing of the products. Product engineering and cultivation of industrial crops has aim to create sustainable solution, enhancing the resources, long lasting and biodegradable materials

Keywords: Industrial crops, cultivation and processing of industrial crops, Importance of industrial crops, Technologies of Product engineering, Raw materials by industrial crops.

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I. INTRODUCTION

Industrial crops are also known as non-food agricultural crops or non-food crops. And these crops are cultivated for industrial and commercial uses. These crops plays major role in environmental preservation and economic growth. And these crops are cultivated especially for their unique properties, which are valuable in industrial products like cosmetics, biofuels, textiles, pharmaceuticals etc. (Fairless et. al, 2007). These industrial crops provide so many use full raw materials and feed stocks, which reduced our using of infinite fossil fuels and contributed to a greener and sustainable future. Some commonly cultivated industrial crops like Jatropha, sugarcane, swish grass, castor bean, cotton soybean and more. Most of the industrials crops are used as biofuel and in pharmaceutical fields (Brennan et. al, 2010). Cultivation of industrial crops have the ancient long history, these crops are cultivated since from ancient civilization (Asif et. al, 2017).

Product engineering is a multidisciplinary field that focuses on processing, development, designing, innovation of products and everything which have role with product. It also involved of transforming of products and marketable products which reached and fulfilled the customer needs, cost effective, maintainable and delivers value (Reinertsen et. al, 2009). It involves collaboration between various teams like product manager, food security, designers, engineers, marketing professionals etc. for ensuring and testing of products. There so many techniques and methods in product engineering, which starts from collecting of product material and end at delivered to customer (Ulrich et. al, 2015). It includes the optimization of cultivation, harvesting and processing of crops, and also generating of valuable materials for commercial uses and commodities (Hayes et. al, 2016). The main objective of industrial crops and products engineering was to carry out the sustainable agricultural practices, which will give result for production of renewable resources and bio based materials which can replaced as fuel based products. Play crucial role in advancing of agricultural and industrial sectors and promoting environmental friendly practices and also in field of food security (Boon et. al, 2021).

II. INDUSTRIAL CROPS

Industrial crops are also called as non-food crops and cash crops. These crops play crucial role in providing raw materials for wide range of industries. The main characteristics of industrial crop which differentiate from traditional crops are their specific uses and industrial uses (Duke et. al, 1981). Industrial crops cultivated primarily and provided valuable resources to the various industries. These crops used in manufacturing, energy production, and other commercial applications (Abd El-Wahab et. al, 2021).

Some Industrial Crops include

1. **Cotton (*Gossypium herbaceum*)**: A widely cultivated crops, which used in textile industries for manufacturing of different clothes, papers, oils, dresses etc. And it gives fibers as raw materials (Wayne Smith et. al, 1999).

2. **Sugarcane (*Saccharum officinarum*)**: It primarily cultivated for sugar production, it is a versatile industrial crops which used to production of molasses ethanol, sugar etc. It

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serves crucial components to the industries for production of different foods and beverages. It is also an important source of biofuels (Wiley-Blackwell et. al, 2013)

3. **Jute (*Corchorus capsularis*)**: Jute produces most important raw materials, which most commonly used in our daily life. Jutes are used for making sacks, bags and so many. It most commonly used in textile industries and in carpets. It mostly used in textile industries for carpets, rugs etc. (CABI et. al, 2015).

4. **Rubber (*Hevea brasiliensis*):** The latex from rubber plants is used for production of natural rubbers. These matters are essential for manufacturing of latex products, tires and many more (Maurice Morton et. al, 1998)

5. **Kenaf (*Hibiscus cannabinus*):** The bast fibers of kenaf are used in textile manufacturing, papers and composites. By the bast fibers, there is also production of insulating materials (Wankhade et al, 2018).

6. **Soybean (*Glycine max*)**: Soybean is the versatile industrial crop, which provide oil for the production of biodiesel, it also very rich in protein. There also production of animal feed by industrial processes (Lawrence et. al, 2008).

There are so many such industrial crops which are cultivated for the production of raw materials by industries and factories, and these manufacturing products are used commercially.

III. TYPES OF INDUSTRIAL CROPS ON THE BASIS OF DIFFERENT REGIONS

There were also different types of industrial crops which are grown vary according to the different regions. The regions are like-

1. Tropical Regions

- **Oil Palm Tree:** Palm oil was extracted and used in food and also in non-food industries. Mostly found in areas like Indonesia, Malaysia, Thailand, Nigeria, Columbia, etc.
- **Rubber Plant:** Latex was extracted from these plants and used by different tire, rubber and gloves manufacturing industries. Mostly cultivated in areas like Southeast Asia, India (Kerala, Tamil Nadu, Karnataka), Nigeria, Liberia, South America, Brazil
- **Sugarcane:** Manufacturing of sugars and used as a biofuel production. Mostly found in areas like Brazil, India, China, Thailand, Indonesia, etc.(de Souza et al, 2018)

2. Subtropical Regions

- **Cotton Plant:** It cultivated mainly for the fibers and supplied to the textile industries for the production of textiles. Mostly cultivated in areas like U.S Texas, Georgia, southern states of U.S, Maharashtra, Gujarat, Telangana, China, Brazil, Uzbekistan etc. (Basra et. al, 2010)
- **Coffee Plant:** Cultivated for fruits mainly and production of coffees powder or may be for flavors. Mostly cultivated in areas like Tropics of Cancer, Brazil, Colombia,

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Mexico, Uganda, Kenya, Tanzania, Southeast Asia, Karnataka, Kerala (Delgado et. al, 2017).

3. Mediterranean Regions

- **Olive Trees:** It was an industrial crops and extraction of olive oil in many industries and used as a drugs and massage and many more. Mostly found in areas like in Spain, Italy, Greece, Turkey, Morocco etc. (Lavee et. al, 2012)
- **Almond Trees:** From almonds, there are manufacturing of so many industrial products like cosmetics, almond oil, for flavoring etc. Mostly found in California, Spain, Italy and Australia (Fawole et. al, 2013).
- **Herbs and Spices:** There were cultivation of so many herbs and spices which are supplied to spices industries, pharmaceutical and cosmetic industries. Crops are like saffron, Basil, Oregano, Thyme, etc. Mostly found in Mediterranean areas (Nencini et. al, 2018).

4. High-Altitude Regions

- **Barley:** It was cereal crops and well suited cultivation in higher altitude. It was used in various animal feeds and malt production. Mostly found in Russia, Germany, France, Canada, North America, Europe, China, etc.
- **Quinoa:** It is the highly nutritional pseudo-cereal crop. The fruits and seeds are supplied to the pharmaceutical industries and also used in so many dishes. It was antioxidant and so many antimicrobial properties. Mostly found in areas like Peru, Ecuador, Colombia, Bolivia, etc.
- **Hops:** Hops plants are essential for beer production and used by beer manufacturing industries. And these plants are cultivated in mostly high altitudes. Mostly found in U.S Washington, Oregon, Germany, Slovenia, Tasmania, New Zealand, etc. (Bazile et. al, 2015)

There are so many industrial crops cultivated or grown in so many different types of regions in earth.

5. Commonly Cultivated Industrial Crops and its Growing Conditions

- **Cotton:** Cotton is often grown using conventional tillage, which involves ploughing the soil to prepare it for Cotton thrives in dry and warm climates and requires well-drained soil as well as 5-6 hours of direct sunlight per day. Farmers typically plant cotton in rows and may use irrigation to supplement rainfall. Conventional tillage, which involves ploughing the soil to prepare it for planting, is commonly used when growing cotton (Ali et. al, 2020)
- **Sugarcane:** Sugarcane is commonly grown in tropical or subtropical regions that have well-drained soil and plenty of water. Farmers typically plant sugarcane using cuttings from mature plants and may use irrigation to supplement rainfall. To reduce erosion, minimum tillage is often used when growing sugarcane, which involves disturbing the soil as little as possible (Singh et. al, 2015).
- **Corn:** Corn usually grows well in warm, temperate climates and requires well-drained soil and at least 6 hours of direct sunlight per day. To grow corn, farmers

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typically plant it in rows and may use irrigation to supplement rainfall. Conventional tillage, which involves ploughing the soil to prepare it for planting, is often used when growing corn (STOLL & Saab, 2015).

- **Soybeans:** Soybeans thrive in warm, temperate climates and need well-drained soil and at least 6 hours of direct sunlight per day. Farmers typically plant soybeans in rows and may use irrigation to supplement rainfall. To reduce erosion, minimum tillage is often used when growing soybeans, which involves disturbing the soil as little as possible (Cartter et. al, 1962).
- **Palm oil:** Palm oil commonly grows in tropical regions that have well-drained soil and plenty of water. Farmers usually grow palm oil in large plantations and may use irrigation to supplement rainfall. Conventional tillage is often used when growing palm oil, which involves ploughing the soil to prepare it for planting (Tan et. al, 2009).

Cultivation techniques for cotton, sugarcane, corn, soybeans, and palm oil can vary depending on factors such as soil type, farming practices and climate. Nonetheless, there are some common techniques used for growing these crops.

IV. TECHNOLOGIES USED IN INDUSTRIAL CROP'S CULTIVATION

1. **Cotton:** Technologies used in cotton farming include genetically modified cotton varieties; integrated pest management techniques and Precision irrigation. Genetically modified cotton can resist pests or herbicides. Precision irrigation can also help reduce runoff and to conserve water. Integrated pest management involves using a blend of techniques to control pests, such as crop rotation, targeted pesticide use and natural predators (Lu et. al, 2022).

2. **Sugarcane:** Sugarcane farming employs several technologies, including precision agriculture, biological pest control, and the use of machine to harvest crops. Precision agriculture optimizes farming practices using data and technology, such as targeted application of fertilizers and pesticides. Biological control uses natural predators or pathogens to manage pests. The Machine harvesting can increase efficiency and reduce expenses associated with hiring and managing labor (Bordonal et. al, 2018).

3. **Corn:** In order to grow corn, farmers use a variety of technologies, including precision agriculture, genetically modified corn varieties, and conservation tillage. Precision agriculture helps to efficiency inputs and reduces waste, while genetically modified corn can resist pests and herbicides. Conservation tillage involves reducing soil disturbance during planting and harvesting to improve soil condition and reduce erosion (Akhtariev et. al, 2021).

4. **Soybeans:** To grow soybeans, farmers use a variety of technologies, such as seed treatments, precision agriculture, genetically modified soybean varieties. Precision agriculture can help reduce waste and efficiency inputs while genetically modified soybeans can resist pests and herbicides. Seed treatments can help prevent pests and diseases from affecting the soybean seed. This can improve the quality of the crop and increase yields (Ergashovich et. al, 2022).

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5. **Palm Oil:** To grow palm oil, farmers use several technologies, such as precision agriculture, mechanized harvesting, and satellite mapping and machine. Precision agriculture can help better inputs and reduce waste, while mechanized harvesting can increase efficiency and reduce labor costs. Satellite mapping can help monitor land use changes and deforestation, which are important in the palm oil industry (Basiron, 2007).

Modern agriculture uses a variety of technologies to increase productivity, sustainability and efficiency. The types of technologies used for growing cotton, sugarcane, corn, soybeans, and palm oil are just a few examples. By using these technologies, farmers can improve crop yields, protect the environment and also reduce waste.

V. HARVESTING METHODS OF SOME COMMON INDUSTRIAL CROPS

1. **Cotton:** Cotton is mainly harvested by machine; a cotton harvester is used to mechanically pick the cotton from the plants. Which can either pick the cotton by hand or from the bolls strip the cotton, after the cotton is harvested, it is transported to a gin where the fibre is separated from the seeds.

2. **Sugarcane:** Sugarcane can either be harvested by hand using machetes or by machine using harvesters that cut the sugarcane and strip the leaves. After the sugarcane is harvested, it is transported to a mill where the juice is extracted and processed into sugar.

3. **Corn:** Corn is harvested by machine using a combine harvester that cuts the stalks and separates the kernels from the cobs. The harvested corn is then transported to a grain elevator where it is stored and processed (Singh, B. P., 2010).

4. **Soybeans:** Soybeans are harvested by machine using a combine harvester that cuts the plants and separates the beans from the pods. The harvested soybeans are then transported to a grain elevator where they are stored and processed.

5. **Palm oil:** Palm oil is harvested by hand using long poles with sharp blades to cut the fruit clusters from the trees. The harvested fruit is then transported to a mill where the oil is extracted and processed.

Overall, the harvesting of industrial crops can be requiring specialized equipment. However, modern farming practices and technology have made the process more efficient and sustainable (DEGEFA, S., & SAITO, 2016).

VI. THE PROCESSING OF INDUSTRIAL CROPS

It can vary depending on the specific crop and the intended use. However, here are some general examples of how some industrial crops are processed:

1. **Cotton:** Cotton is processed by first transporting the harvested cotton to a gin where the fibre is separated from the seeds and then the fibre is spun into yarn after cleaned and carded. After that it knitted into fabrics.

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2. **Sugarcane:** Sugarcane juice is processed to make raw sugar. First of all the juice of sugarcane is extracted and processed into raw sugar after the harvested sugarcane is transported to a mill. The raw sugar which is obtained from sugarcane juice is then refined and processed into granulated sugar. Molasses and bagasse are the by-products of sugar processing. The Molasses and bagasse can be used to make animal feed and ethanol (Momayez et. al, 2019).

3. **Corn:** Corn kernels are turned into flour, meal, corn oil, and corn starch. Additionally, corn is used for ethanol production as a feedstock. The harvested corn is stored and processed after transported to a grain elevator. Flour or meal, Corn oil and corn-starch extracted from the kernels.

4. **Soybeans:** It is processed into food and some industrial products. The harvested soybeans are stored and processed after transported to a grain elevator and to extract oil the beans are crushed, this oil are used for cooking purposes and also used for industrial applications. Animal feed and food products like tofu and soy milk are obtained from the remaining soybean meal (Gasparatos et. al, 2021).

5. **Palm oil:** Palm oil is processed into so many products like food, cosmetics, and biofuels. The oil is extracted and processed in a mill where the harvested fruit is transported. The oil which is extracted from the fruit can be refined and processed into a variety of products, such as soap, cooking oil, margarine, shampoo, detergent etc.

VII. IMPORTANT APPLICATIONS OF INDUSTRIAL CROPS

Biofuels: Biofuels are a cleaner and sustainable alternative to fossil fuels, which helps to reduce greenhouse gas emissions and combat climate change. Industrial crops such as sugarcane, soybeans, corn can be used to produce biofuels.

1. **Textiles:** Industrial crops like cotton, hemp, and flax are used to manufacture textiles. These materials are used to make clothing, bedding, and other household items (Germing et, al, 1975)

2. **Food:** Some industrial crops, such as corn and soybeans, are used to obtain food. These crops are used to make a variety of food products, including corn syrup, corn flour, vegetable oil, and tofu.

3. **Biodegradable plastics:** Industrial crops such as corn and hemp can be used to produce biodegradable plastics. These plastics are designed to break down quickly in the environment, which can help reduce plastic pollution (Fernando et. al, 2015).

4. **Land restoration:** Some industrial crops, such as switch grass and willow, can be used to restore degraded land, improve soil quality, and prevent soil erosion. This can help protect the environment and support sustainable agriculture (Lal et. al, 1992).

Industrial crops applications which help promote sustainability and reduce the environmental impact of various industries.

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Table 1: Tabulation of Some Industrial Crops, It's Raw Materials, From Which Part Raw Material Extracted and Its Locations

Sl. No.	Crops Name	Product	Part of Crop Used	Location of Crops
1	Cotton (*Gossypium herbaceum)*	Cotton fiber	The seed-hair (fiber) of the cotton plant.	Grown in warm climates worldwide, major producers include China, India, and the United states.
2	Sugarcane (*Saccharum officinarum)*	Sugar (sucrose)	The stalk of the sugarcane plant contains the sugar-rich juice.	Primarily grown in tropical and subtropical regions like Brazil, India, and Thailand.
3	Corn (Maize) (*Zea mays)*	Cornstarch, corn oil, ethanol, and animal feed.	The kernels are processed to obtain various products.	Widely grown in the Americas, especially in the United States, China, and Brazil.
4	Wheat (*Triticum aestivum)*	Flour for bread and bakery products.	The seeds (grains) are milled into flour.	Major wheat-producing regions include China, India, and Russia.
5	Rice (*Oryza sativa)*	Rice grains (for food).	The seeds (grains) are harvested for consumption.	Mainly in regions China, India, Indonesia
6	Palm Oil (*Elaeis guineensis)*	Palm oil for cooking and various industrial uses.	The oil is extracted from the fruit's flesh.	Mainly cultivated in tropical regions, such as Indonesia, Malaysia, and Nigeria.
7	Rubber (*Ficus elastica)*	Natural rubber for tires and other rubber products.	The latex is tapped from rubber trees.	Predominantly grown in Southeast Asian countries like Thailand, Indonesia, and Vietnam.
8	Tea (*Camellia sinensis)*	Dried tea leaves for tea production.	The young leaves and buds of the tea plant are harvested.	Grown in countries with suitable climates, including China, India, and Kenya.
9	Coffee (*Coffea arabica)*	Coffee beans for coffee production.	The seeds (coffee beans) are roasted and ground to make coffee.	Major coffee-growing regions include Brazil, Colombia, and Vietnam.
10	Sisal (*Agave sisalana)*	Sisal fibers for rope, twine, and other products.	Fibers are extracted from the leaves of the sisal plant.	Mainly grown in arid regions of Brazil, Tanzania, and Kenya.
11	Jute (*Corchorus capsularis)*	Jute fibers for sacks, bags, and other products.	Fibers are obtained from the stem of the jute plant.	Mainly cultivated in India, Bangladesh, and China.

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12	Flax (*Linum usitatissimum)*	Line fibers for textiles and linseed oil.	Fibers are obtained from the stem, and linseed oil comes from the seeds.	Grown in various temperate regions, including Canada, Russia, and China.
13	Rapeseed (Canola) (*Brassica napus)*	Canola oil and animal feed.	The seeds are crushed to extract oil and used as animal feed.	Major producers include Canada, China, and India.
14	Safflower (*Helianthus annuus)*	Safflower oil, dyes, and cosmetics.	Oil is extracted from the seeds, and the flowers are used for colorants.	Grown in regions with a dry climate, such as India, the United States, and Mexico.

VIII. PRODUCTS ENGINEERING

Product engineering was the multiple fields of approaches that involves developing, designing, refining, processing and so on with this optimize of the products throughout their life cycles. It follows many processes or stages like ideation, prototyping, and testing, manufacturing and proper improvement of products (Kalaskar et. al, 2019). The main motive was to fulfill the customer needs by manufacturing the product in high and good qualities with innovatively. The different stages of product engineering are like ideation, designing, prototyping, development, testing, manufacturing, production, launch, and supports (Rathi et. al, 2020).But if the product engineering comes under the industrial crops there are so many stages of production of raw materials, which starts from crop selection and ends at quality control or products storage facility (Yadav et. al, 2019).

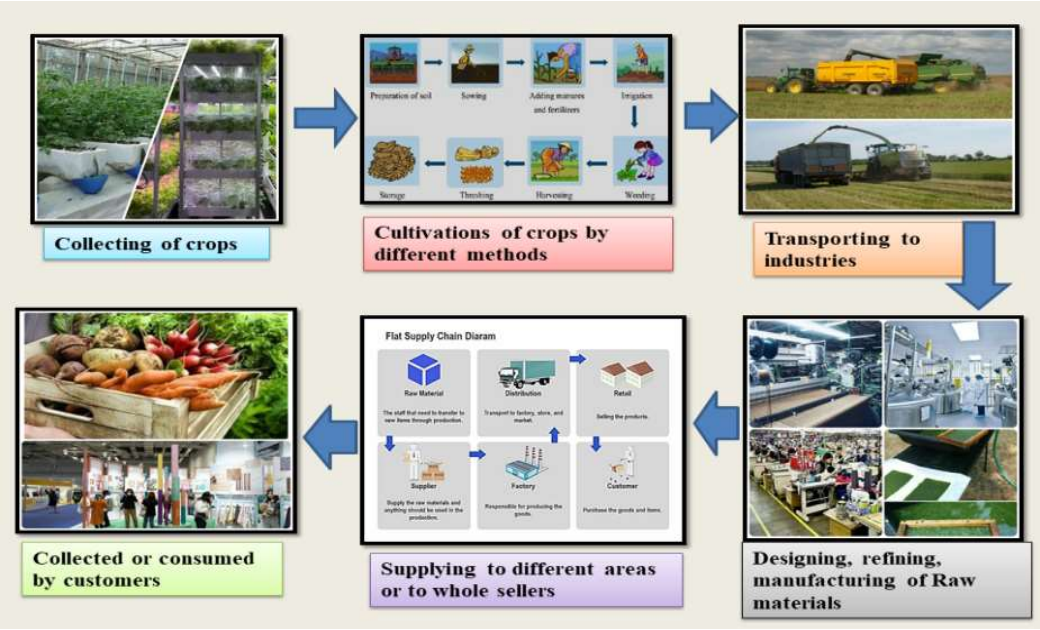

Figure 2: Product Engineering Basic Stages

IX. COMMON AND BASIC PRODUCT ENGINEERING TECHNOLOGIES

There are so many technologies are used to increase the productivity, quality, quantity and efficiency of the crops and raw materials. It also speeds up the works and in good manner. So some commonly used technologies in product engineering are-

1. **Precision Agriculture:** This technology contains sensor, monitor, drones and GPS, which plays important role in increasing the product quality and quantity. It works as in very efficient manner. By help of these we can detect the defective crops, disease crops in small amount of time. And provide adequate amount of fertilizers and water (Prasad et. al, 2016).

2. **Genetic Engineering Technology:** These technologies are the latest technologies, and it play very important role in crops development and in product engineering. It can improve the crops quality and quantity by making the plant disease resistance and also possible to various varieties of crops were cultivated. It increases the nutritional content of the plants, improved the traits and high yield (Huang et. al, 2016).

3. **Bio Refinery:** It is the important process and technology in product engineering. This technology refined or simplified the complex into simple and useful products. It converts the biomass into biofuels, bio plastic, environmental friendly products and biochemical. It is a refining process (Ahmad et. al, 2017).

4. **Automation and Robotics:** These technologies are more advanced and new generation technologies. These advancement of crops and products, also speed up the processing of raw materials. It automatically works and analyze the defective products and detect the damaged our diseased plant in widely. Now days these technologies are used in farming, cultivation, post harvesting techniques etc. (Rovira-Más et. al, 2017).

5. **Hydroponics and Aeroponics:** It is the latest technologies, in which cultivation of large amount of crops without soil. It is the soilless farming; we can increase the quality of crops and also quantity. And these technologies are also followed by many industries for good quality of crops. In this technology plant are grow in nutrient rich water and aeroponics, plant roots are remain in air and treated with nutrient rich solution for better growth (Savvas et. al, 2018).

6. **Post-Harvest Technologies:** This technology was used by most of the industries to speed up the supplying and production processes. Machinery was used in these technologies. Extract the raw materials from the crops, preservation of the raw materials or crops, storage facility, transporting, control the quality of the products, maintaining the atmosphere for the crops and raw materials, packaging of products etc. these are the mechanisms followed by post harvesting technologies (Rahman et. al, 2019).

There are so many technologies and processes in product engineering. It also essential and make the works so easy and fast. New generation technologies were now days invented like artificial intelligence (AI) which is more helpful and plays various significant role in product engineering and in daily life too. It detect the defective products at wide range, speed up the manufacturing, analyze the product in small time,

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use algorithms and databases to improve the products and its quality, etc. there are so many beneficial mechanism of the AI in various industries (Duan et. al, 2019).

X. CONCLUSION

Industrial crops are mainly nonfood crops and these crops are cultivated for supply to different industries for product engineering as a result production and manufacturing of raw materials. So these crops play important role in industries and providing renewable resources to industries for product engineering. These industrial crops offer sustainable raw materials and reducing the environmental impact. For extraction or utilization of industrial or no food crops, products engineering field has important role. Because in product engineering there are various mechanism, ideas, processing, refining, technologies, stages and many more contain which advancement or extracted useful materials from different industrial crops. Due to innovative and multiple products engineering mechanism and technologies, these crops were able to resulting of bio based material, biofuels and many more eco-friendly products and it also provide sustainable future. So the main motive is that the combination of product engineering and industrial crops gives rise to major resources and renewable products and ecological friendly materials.

XI. ACKNOWLEDGEMENT

This works was supported by Dr. R. Pravallika Sree and thanks to all authors for contribution. We all are thanks to C.V Raman Global University for this work.

Conflict of Interest: The authors declare that they have no conflict of interest.

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