Chapter 8

Overview of the Degradable Plastic Market

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Abstract

Degradable plastic manufacturing has emerged as an eminent industry due to multiple range of products it offers to the consumers. The diversity induced by the usage of biomaterials lures the customer, making it even more popular for consumption. Degradable plastic industry is a market of multifarious products. The backlash on the massive plastics consumption is expected to be eradicated in the wake of the large business market of degradable plastics in the coming years. The supremacy of the degradable plastic market is not easy to evade by any means. The degradable plastic market is not a solitary market; instead, it encompasses the production, consumption and recycling industry as well. In order to triumph the status of a flourished market a joint venture by the leading companies need to be in harmony. The circular economy of the world is indispensable without a degradable plastic market in future.

Keywords

Bioplastics, Feed Stock, Circular Economy, Global Plastic Market, Degradable

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1. Introduction

The necessity and utility of the plastic goods are always undeniable. However, the global concern towards environment induced a huge change in the infrastructure of the plastic market. When the plastics were introduced to the world in “twentieth century”, the popularity of plastic was due to easy and economical access to everyone. It is logical, this easy availability is due to convenient production, cost reduction and availability of manpower. These plastics provide multiple competitive features; these are resilient, lightweight, transparent, gauzy, and flamboyant. These materials exclusively display the design representation, performance and mass production capacity, in contrast to other alternative materials such as steel, aluminum or glass etc. The availability of plastic goods is beyond our envision. We just contemplate about a product, and the plastic industry makes it a reality. It is surly the diligence and commitment of the plastic manufacturers thriving this industry to the place where it is today.

Its vibrant features make them superlative for all sort of packaging, construction, horticulture, textile sanitation, agriculture, transportation, furniture, electrical products, consumer product, electrical products, cosmetics, etc. Despite the excessive availability of plastic products and its easy availability, consumers are now more conversant and alarmed about the environmental problems instigated by plastics. The prime anxiety is developed due to health and environmental concern in connection with proper plastic litter disposal. This awareness has revolutionized this industry into a degradable plastic market. The consumer’s choices to use this new “degradable” or “bioplastic” are in fact booming the industry without affecting its production as shown in Fig. 1. It would be bigoted not to give credit to the plastic manufacturer to covert conventional plastics products into degradable plastic according to the customer and environmental demand. There are numerous examples of non-optimized, low-cost and short-life cycle plastic products that are typically lucrative for the manufacturer but eventually end up as

undisposed waste on the credit of consumer. However, the strategic planning of the plastic manufacturer led the foundation of a new plastic industry in the form of degradable plastics. Now this innovative plastic industry elevates a big question of how these degradable plastics are produced apart from conventional plastics. Undoubtedly, if not all, yet a few ingredients must diverge in these degradable plastic products. When the customer thinks about the degradable plastic, it doesn't mean an exorbitant disposal method instead it is looking for an eco-friendly method, or even with the possibility of recycling the products without negotiating the price of the product. Contemporary environment of competition in the global economy helps to ensure the quality of product. The smart manufacturer has actually created a smart market of degradable plastics for consumers [1].

Fig. 1 Emergence of degradable plastic industry in all practical fields.

2. Conversion of nondegradable to degradable plastic market

Plastics are one of the most ubiquitous products of our routine life. Their extensive applicability has widened their market inducing a number of advantages in various sectors, engendering numerous benefits for society and ecosystem. The voluminous plastics market is thrashing the other markets of paper, wood, aluminum. Their extraordinary properties have introduced them as an important part of various other

sectors as well, this is one of those industry which is bifurcated into multiple industries. The plastics are serving two most important sectors of food and automotive industry [2]. As a matter of fact, the whole world is using the plastics however a few countries are leading in the market. China is one of the major plastic producers in the world, its plastic industry started to develop in early 1950s, it was the era of the discovery of crude oil and its significant industrial consumption for synthetic polymers. Within forty years China had more than 200 huge plastics manufacturing amenities. It utilized linear low-density polyethylene, polystyrene, acrylonitrile-butadiene-styrene as major plastic products. It introduced the plastic products in agriculture, packaging, construction and automotive. The China's plastic industry is mature now and can afford to turn towards a degradable plastics market. Hence, China which is usually considered one of the largest polluters globally; actually introduced a ban on non-degradable plastics in 2008. Fig. 2 shows a systematic evolution of biodegradable plastics from nondegradable plastics [3]. Surprisingly, the hazards related to plastics were not taken seriously by the developed countries rather every country played a vital role. Bangladesh was the first country to ban certain kinds of plastic bags in 2002. California was the first US state to endorse a plastic bag prohibition in 2014, followed by Idaho, Arizona, and Missouri between 2015 and 2017. In 2017, the European Union decided to make all plastic packaging recyclable or reusable by 2030; lastly Italian law has banned plastic bags for fruit, vegetables and baked goods. These initiatives were the prime reason to develop and promote the bioplastic industry [4].

The bio-based degradable plastics have experienced revitalization in the recent years. Primarily there are three groups of biobased polymers which are used as bioplastics as well, it includes: “**biochemosynthetic polymers**”, such as polylactic acid (PLA), polybutylene succinate (PBS), polyvinyl alcohol, and polyglycolic acid; biosynthetic polymers, which are also known as bioplastics; “**naturally occurring polymers**”, such as polyhydroxyalkanoate (PHA), and “**modified natural polymers**” such as starch polymers and cellulose derivatives [5]. Starch and polylactic acid (PLA) emerged as renewable feedstocks. This plastic is an excellent option for switching from conventional plastic to bioplastic due to nominal CO₂ emission contributing to global warming. The spectacular transition of non-degradable plastics to degradable plastics has changed the degradable market scenario [6]. The second most abundantly used degradable plastics are soybean based bioplastics. The US is major soybean producer in the world with 82.05 million metric tons. In the European plastic market, large supermarkets such as Sainsbury and Tesco took the initiatives to use biodegradable shopping bags [5]. Numerous renowned consumer and multinational companies have started using bio based materials as part of their sustainability programs. Some foremost examples in this connection are:

- Johnson & Johnson, started using biobased polyethylene packaging for sunscreen products in Brazil in 2009.
- Procter & Gamble, unveiled its long- term vision on 2010 by the use of 100% renewable materials or recycled for all products while eliminating the use of all petroleum-based virgin plastic and PVC-based plastic. P&G perceived the challenges of bioplastics due to lower availability of resources and difference in prices. In the market it is actually not easy to promote bioplastics as mainstream consumers will not pay more for bioplastics.
- Coca Cola also used biobased materials [5]. The world's consumption of bioplastics has increased from 15,000 tons (in 1996) to 225,000 tons (in 2008). With increasing demand for the world's plastic consumption, it was expected that the demand for biodegradable plastics will grow by 30% each year. These growing demands can only be met by exploring new bioplastic materials [7].

Fig. 2 Transition of global non biodegradable plastic to biodegradable plastic industry ;(A) Representing the discovery of petroleum based non degradable plastics, (B) representing the issues created by the non degradable plastics (C) Struggle to find alternate resources (D) Successful development of degradable bioplastics.

3. Associated markets for degradable plastics

The bioplastic market is not a single unit rather it comprises two other industries as well.

- Production industries of degradable plastics
- Consumption industries of degradable plastics

3.1 Production industries of degradable plastics

Developing a new market for bioplastics was very challenging because their competitors were well developed petrochemicals, which had a trusted fame in the entire polymer supply chain. It became more challenging as the Middle East was the hub of the petrochemicals. Despite these factors, major investments were made for new bio-based plastics which revealed a significant potential of bioplastics transforming the production of nondegradable plastics to a new field. The convenience of conversion of nondegradable plastics to the degradable plastics was in the hope of availability and utilization of biomass. Hence several biomaterials have been used for the production of bioplastics.

There method can be adopted to produce bio-based plastics, i.e.

- i) Modification of the natural biomaterial for the conversion to bioplastics, e.g. starch plastics
- ii) Conversion of monomers to bioplastics by the process of fermentation followed by polymerization such as: polylactic acid
- iii) Production of bioplastics from monomers by micro-organisms such as; genetically modified crops.

When the production of any product achieves the highest position in the market, then it is not the product market only, actually there are multiple associated markets which develop with the main product as well. The most important plastic raw materials are: “**Starch plastics**”. These starch plastics are leading the degradable plastics for two decades of evolution of bio-based plastics. These plastics are enjoying the experience of massive growth in its production. This is one of the widely used commercialized, degradable plastic in the market, used with the intention to replace non-biodegradable plastics. This inexpensive raw material can be blended with other copolymers to achieve the desired characteristics. The European countries optimized the starch production to approximately 130,000 metric tons from 2003 to 2007 representing an annual growth rate of nearly 50%. Five main types of starch can be obtained from the processing step, including: *Moderately fermented starch*; used primarily for those applications where the mechanical properties can be compromised. 2. *thermoplastic starch*; used for blending with other

polymers to produce starch blends such as foamed-trays and boxes especially in food packaging, water soluble products and ingestible products. 3. *chemically modified starch*; expensive and not in excessive use, 4. *starch blends*; high water vapour permeability of starch plastics as fog-free packaging of warm foodstuffs. These are also used in catering service such as cups, food trays, knives and forks etc. 5 *Starch composites*. A native starch based composite blended with one or more constituents to enhance the properties of the main starch stream, coupled with the spark in the properties of the product [3]. The “Cellulose Plastics” industry is in a mature state with moderate growth because of China’s remarkable role in flourishing its market. The main types of cellulosic plastics are *Organic cellulose esters* and *Regenerated cellulose*. The organic cellulose esters were developed to supplement cellulose nitrate to avoid its flammability resulting in its market today. Approximately 20% chemical grade pulp produces organic cellulose ester. Which is used in packaging films, cigarette filters, textile fibers, surface coatings, pharmaceutical (sustained release) and many other specialty industrial applications? The *Regenerated cellulose* is a widely used product. Almost 60% of the worldwide use of chemical grade pulp is consumed to produce regenerated cellulose fibers and films, suggesting fibers economically more favorable [8]. ***Poly(lactic acid) (PLA)*** is an aliphatic polyester production was started to be used in 2002 by NatureWorks’ (formally Cargill Dow) production plant and became the third type of bio-based polymer that was commercialized and is now produced on a mega scale. Dupont, Coors Brewing (Chronopol) and Cargill all these companies have significantly contributed in large research and development programs to investigate the possible technical applications for lactic acid, lactide and PLA. The important applications of this plastic are; extruded sheet, biaxially oriented film, blow moulded bottles, injection moulded products, packaging products including (cups, bottles, films, trays), textiles (shirts, furniture), nonwovens (diapers), electronics etc. ***Poly(trimethylene terephthalate) (PTT)***; This material was developed with the aid of processability of polybutylene terephthalate (PBT) in order to overcome the rigidity of polyethylene terephthalate (PET). The resiliency, wearability, dyeability, static and resistance made it a favorite choice for carpets and industrial textiles. In 2001, PTT Poly Canada, a joint venture between Shell Chemical and SGF Chimie JV, was formed to produce petrochemical PTT on a scale of 95 kt.p.a. in Montreal, Canada; the plant was operational in 2004. ***Bio-based polyamides (nylon)***, This is a product of castor oil, bio based adipic acid, *based azelaic acid*, *bio-based caprolactam dealing in automotive industry Arkema* (formally AtoFina) is the only producer of only producer of PA from castor oil. The production plant is located at Marseille Saint Menet (France). The manufacturing capacity is 22,000 tons/year in Europe. Arkema’s PA11 has the tradename Rilsan. It is produced in France (Serquigny), in China (Changshu) and in the USA (Birdsboro, PA). ***Soy-based***

Polyhydroxyalkanoates (PHA) Soybean oil is an attractive carbon source for the production of PHA as it supports the yield of PHA from soybean oil ranged from 0.72 to 0.76 g/g and the PHA productivity was around 1 g/L/h [6].

3.2 Consumption industries of degradable plastics

There are various consumption sectors of the biobased materials and many companies took the initiatives and played leading role in order to promote the degradable plastics. Procter & Gamble pledged to reduce petroleum- derived materials by 25%. Eventually, it intended to develop 100% packaging and products with renewable or recycled materials. Similarly, the world famous company “Coca-Cola” company established a global office of sustainability. The appropriate packaging of biodegradable material has a significant advantage over conventional packaging. In the event of the Olympics 2012 organized in London large amounts of starch and cellulose- based packaging were utilized [5]. Various renowned industrial sectors factors have started consuming degradable plastics such as; the food industry. Packaging industry utilizes 41% for plastic packaging for different items among which 20% is earmarked for food. Bioplastics are committed for sustainability and biodegradability to protect the environment and the consumer. A few distinguished companies which are developing bioplastics include: Dow chemicals (EcoPLA), DuPont (Sorona and Hytrel), BASF (Ecoflex and Ecovio) etc. Particularly BASF a famous face of polymers and chemicals has established numerous biobased and biodegradable plastics utilizing starch, PLA, PBAT etc. Ecoflex and Ecovio (a blend of Ecoflex and PLA) are both made of biodegradable plastics are extensively used materials in packaging specifically in shopping bags. Additionally, many other companies such as; Nature Works, Environmental Polymers, Novamont, Mirel, Tianan, Innovia etc. are developing bioplastics from renewable sources. Despite of exceptional features of bioplastics it still is a big task to replace petroleum based non degradable plastics entirely from the market [8]. “**Engineering Applications of Bioplastics**”, bioplastics also deliver an ecological substitute for building and construction market. These materials are converted into biocomposites to get the maximum benefits. “**Biomedical Applications of Bioplastics**”, the revolutionary use of bioplastics in medical industry is bringing more advantage than we have ever imagined. New materials are being reconnoitered for usage in the broad spectrum of biomedical applications for instance; implants, tissue engineering, drug delivery etc. [7-9].

4. Challenges of degradable plastic market

Whenever there is emergence of a new market, it is not devoid of hurdles, struggles and challenges. It is not a one day practice to think and to create especially when it is a global

market issue. It is a real blessing for mankind that the proprietors of the leading companies took the special initiative to convert their non degradable products into degradable products. All the countries specified the legislations to control the hazards associated with the non degradable issue. Currently, these industries are flourishing rapidly, however as a matter of fact it is not easy to convert the nondegradable plastic market to degradable plastic market rapidly. The most important challenges faced by this industry is given below:

4.1 Consumer acceptance

The market relies on two important figures; in the market there is a strong relationship between the consumer and the product. The bioplastic industry is yet not as flourished as plastic industry. In the beginning of the plastic industry, its popularity was associated with its low cost and long shelf life. Both are conversed features of bioplastics, where there is greater investment and the ultimate degradation. Hence, it is actually difficult to convince people to buy the products wrapped in bioplastic and to accept not only its higher price but to make them aware with the responsibility to dispose of the wrapper according to prescribed protocol as well. This also involves using only right packaging otherwise, the customer will be reluctant to buy products due to limited shelf life and probability of quick degradation of packaging. It is actually the maturity and preference of the customer to buy the product with degradable packaging. Corporate's social responsibility also urges them to promote various activities in all market areas with the specific concerns to aware the customer about environmental protection and to switch towards their new product. Awards are given to companies who have worked remarkable in the field of environmental awareness. The UK provides special training regarding the control of climate change. By the interest of many countries and companies, the environmental policies can be adopted easily. The product price plays a significant role to its acceptability to the consumer, this difference is viable in plastic goods, both natural and synthetic plastics follow approximately the same prices even then it's a serious challenge for the bioplastic market to convince customer to ignore the minor difference in the price to create a big difference in the society. The difficulty is the poverty in the world, in the developing and underdeveloped countries it is difficult for the customer to even pay some extra coins to prefer degradable plastic over non degradable plastic. It is a very critical situation where the bioplastic industry has to measures the business opportunity as well. To fix a market price is essential to prevent the market decline. Though, the companies are playing a key role in making the bioplastic products popular among consumer, still they need strategic planning. To compete with petro plastics the bioplastics have to be easily available in the market and it should be really ecofriendly as well [10-13]

4.2 Inadequate availability of biomass feedstock

The bioplastic industry is dependent on the availability of biomaterials. The variable cost of grains impacts the price of bioplastic, which is influenced by grain's stocks and estimation of grain's annual crop price. Inflation in grain's prices due to diminutive production, stock or supply can reduce the production of bioplastic. Hence, it is a real challenge to keep an eye on feedstock all the time and to plan production accordingly. Hence it is significantly different to make a sole synthetic product with the use of biomaterial. Obviously, in this situation the petroleum based non degradable plastic will face less completion, promoting a more intense and challenging situation for bioplastics. The low wastage of biomaterials and the promotion to harvesting is only the right solution for this problem which can help to control the rates of bioplastics. This challenge can also be coped with recycling which however a tedious process. Apart from this, the real challenge is to fill the gap of demand and supply. Once the consumer is convinced to use the bioplastic product there should be no gap in the demand and supply chain [14-16].

4.3 New market of degradable plastics for circular economy

The global economy is oscillating due to drastic changes in international market in recent years, including escalation in demand and prices of crude oil. The linear 'take-make-dispose' economic model is fading, and initiatives to develop alternative economic models are evolving. Circular economy is in limelight. **Fig. 3** represents a relationship between linear and circular economy of degradable plastics. The price change in the stock market is always an issue especially for manufacturing companies. This change is usually associated with the oil price change which could be best situation where bio plastic can replace crude oil products. Similarly, the increase in the price of sugar for the production of bioplastics is also important which can be replaced with more economical corn production. Bioplastic is becoming a vital component in circular economy which can help in transformation of static economy into circular economy. It keeps the resources to circulate continuously. It is degenerated, recycled and reformed again in circular economy. It enhances system effectiveness by enhancing and optimizing the products. [10,17] The global resource ingesting, political, industrial and civil society organizations are progressively solving the puzzle to the resource 'limits to growth. In the European Union, the 'circular economy' has been presented as a high-level approach to move the societies beyond these limits. European policy makers consider the European business community very important to launch such processes. It is assumed that by applying new business models based on circular economy principles, the society will adopt circular economy. However, this assumption has yet to be scrutinized empirically. We know very little about how the business community takes up the circular economy as a potential

strategy and whether and how debates and initiatives towards a circular economy contribute to business innovation. The bio-based sector, as one of the largest producers and consumers of natural resources in Europe, has become a vocal sector in the context of the circular economy particularly in Northern and Western Europe. Despite its relative importance to the European economy, evidence on the impact of the bio-based sector on the circular economy is still residual [11,18].

Fig. 3 Economy cycle of degradable bioplastics.

Conclusion and future prospects

In order to cope with the competitive environment in the petroleum based plastic industry, the launched product should be optimized enough to attract and satisfy the customer. The appropriate resource and raw materials consumption are the key to ensure profit. Degradable plastics are in the struggle to occupy the maximum share of the plastic industry due to its salient features. The degradable plastic and especially the bioplastics have covered a long passage to attain its present status, though it was very challenging to compete the petrochemical plastic industry but it is the global effort with the help of renowned companies to introduce it to the plastic consumer. After the successful production of bioplastic products, the next challenge is to spread the awareness about bioplastic. It is a million dollars industry but the consumer is still reluctant to embrace it fully due to its high cost and low shelf life over conventional plastics. The promising

future of bioplastic will try to eradicate petroleum plastics. Bioplastic industry is committed to diminish the issues of marine litter and fossil fuel waste spreading by using green credentials. However, there is dire need of behavioral changes on bioplastics. Bioplastics have the potential to alter the shape of the economy from linear to circular but it should be in the limit of ethical boundaries. The climate change information suggests that the global carbon and greenhouse gases emission will be worst in condition until 2050. In order to maximize the potential of bio plastics a systematic approach is required through the controlled life cycle of bio plastics to promote it by then. A long path is ahead to realistically achieve this target. This dream can be true by the mass production of feed stock, its preservation, public awareness and only by the ethical constraints worldwide.

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