

# We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

5,800

Open access books available

142,000

International authors and editors

180M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index  
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?  
Contact [book.department@intechopen.com](mailto:book.department@intechopen.com)

Numbers displayed above are based on latest data collected.  
For more information visit [www.intechopen.com](http://www.intechopen.com)



## Chapter

# An Approach to Modify the Current Agricultural and Agro-Industrial Systems into Integrated Bioindustrial Systems and Biorefineries to Develop Sustainable Bioeconomy

*Mohamed Samer*

## Abstract

The existing agricultural and agro-industrial systems are not economically, environmentally, and socially sustainable as they implement the linear mode of production, which should be amended to the cyclic mode of production to promote sustainability. Therefore, this study aims at providing an approach to transform the present agricultural systems (beef, dairy, and poultry farms as well as cereals and vegetable crops production) and agro-industrial systems (ethanol industry and fish industry) into integrated bioindustrial systems and biorefineries by altering their linear mode of production into a circular mode of production to create a coherent bioeconomy, where the bioeconomy includes the conversion of renewable bioresources and waste streams into value-added bioproducts, such as food, feed, pharmaceuticals, nutraceuticals, biomaterials, biochemicals, biofuels, and bioenergy. Whereas the integrated bioindustrial systems allow designing cyclic production and consumption systems to maximize the resources and energy use efficiencies, forming a further ecologically sound and healthy environment through conversion of biowaste into value-added bioproducts, and emphasizing the socio-economic development through creating new employment opportunities and ground-breaking technologies and novel bioproducts. An important key issue is that digitalization is essential to the development of the bioeconomy, where digitalization supports practices innovation by boosting both supply and value chains in the circular bio-based economy.

**Keywords:** bioeconomy, biomass valorization, bioprocessing, bioproducts, biorefinery

## 1. Introduction

Current agricultural and agro-industrial systems apply the linear mode of production and, therefore, the majority of today agricultural and agro-industrial production

and consumption systems are unsustainable. In other words, current agricultural and agro-industrial systems are economically, environmentally, and socially not sustainable. Precisely, the problems associated with nowadays agricultural, and agro-industries are (1) inefficient use of resources, (2) inefficient use of energy, (3) high production costs, (4) high environmental risks, and (5) massive wealth gap between the poor and the rich. Therefore, sustainability is a key issue in this context, where sustainable development encompasses the integration of social and environmental issues with economic development to convene the pressing needs of the population at present without undercutting the requirements of future generations. One key issue is to mimic the sustainable models provided by natural ecosystems. Precisely, turning the linear mode of production (linear economy) into the cyclic mode of production (circular economy). The current farming and agro-industrial processes have two main problems, which are the inefficient use of energy and wastes are not utilized within the production processes, which leads to the degradation of the surrounding environment. In contrast, natural ecosystem -which should be mimicked- allows the efficient use of energy, and all wastes are bioremediated and utilized by the system. Hence, the current farming and agro-industrial processes (linear) should be amended to mimic the natural ecosystem (circular), where this leads to the concept of industrial ecology, which fills the gap between the farming and agro-industrial processes on the one hand, and the ecologically sustainable natural system on the other hand.

## **2. Bioeconomy**

According to the EU, “the bioeconomy encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products, and bioenergy” [1]. Furthermore, “the transition to a more circular economy, where the value of products, materials, and resources is maintained in the economy for as long as possible, and the generation of waste minimized, is an essential contribution to the EU’s efforts to develop a sustainable, low carbon, resource-efficient, and competitive economy. Such transition is the opportunity to transform the economy and generate new and sustainable competitive advantages” [2]. Consequently, the bioeconomy is broader and deeper than a circular economy. On the other hand, biomass is defined as “the biodegradable fraction of products, waste, and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste” [3]. In other words, biomass types are agricultural biomass (crops residues and animal wastes), fisheries biomass, algae biomass, and forest biomass.

Circular bio-based economy aims at reaching a net zero-carbon community by creating sustainable technologies and efficient resource use approaches to substitute the fossil-based economy. The circular bioeconomy primarily depends on biomass as a building block, while social, economic, and environmental are the principal factors. The technologies that are projected to be industrialized under circular bioeconomy must guarantee that the value of product carbon is preserved to decrease the wastewater production, greenhouse gas (GHG) emissions, and impairment to the ecosystems. In the context of circular bioeconomy growth, the biomass production, process advancements, and reuse approaches ought to be well defined to meet the global supply chain and demand. This urges conducting techno-economic assessment (TEA) and life cycle analysis (LCA) of every product and process.

### **3. Bioprocesses and bioproducts**

Bioproducts or bio-based products are biomaterials, biochemicals, and bioenergy derived from renewable biological resources. The biological resources include agriculture, forestry, and biologically derived waste. One of the renewable bioresources is lignocellulose. Cellulose-based materials and lignocellulosic tissues are biologically derived natural resources.

Conventional bioproducts and emerging bioproducts are two broad categories used to categorize bioproducts. Examples of conventional bioproducts include building materials, pulp and paper, and forest products. Examples of emerging bioproducts include biofuels, bioenergy, starch-based, and cellulose-based ethanol or bioethanol, bio-based adhesives, biochemicals, bioplastics, etc. Bioproducts derived from bioresources can replace much of the fuels, chemicals, plastics, etc. that are currently derived from petroleum. As a result, the emerging bioproducts are environmentally friendly products and independent of fossil sources.

Bioprocessing and bioproducts production include the use of engineered microbiological systems for generating biofuels, bioelectricity, and new high-value bioproducts. Additionally, scientists are investigating the utilization of forestry products in untraditional applications, including industrial foams and flame-retardant materials. This needs to combine a conglomerate of mathematics, biology, and industrial design, and consists of numerous varieties of biotechnological processes, which pertain to the design, development, and implementation of processes, technologies for the sustainable manufacture of biomaterials, biochemicals, and bioenergy from renewable bioresources. Bioprocessing deals with the design and development of equipment and processes for making bioproducts such as food, feed, pharmaceuticals, nutraceuticals, biochemicals, biopolymers, and paper from biological materials (i.e., biomaterials). Practically, bioprocessing takes place in devices called bioreactors.

Bioreactors are categorized, based on the mode of operation, as a batch, semi-continuous or continuous bioreactors. Microorganisms growing in bioreactors may be submerged in a liquid medium or may be attached to the surface of a solid medium. The bioenvironmental conditions inside the bioreactor, such as temperature, nutrient concentrations, pH, and dissolved gases (especially oxygen for aerobic processes) affect the growth and productivity of the microorganisms.

### **4. Value-added bioprocessing of biowastes**

Biological wastes i.e., biowastes, generated from agriculture, wastewater treatment, or industry are a largely untapped source for the production of value-added bioproducts or bioenergy. Their recovery utilizes biological and chemical processes that provide alternative sources for chemical feedstocks to produce different products e.g., bioplastics or other biopolymers, high-value biochemicals, protein for animal feed, and enzymes. For example, nutrients, cellulose, volatile fatty acids, extracellular polymeric substances, or proteins can be recovered from biowastes. Similarly, many opportunities exist for alternative energy products, e.g., bioethanol, biobutanol, biogas, biohydrogen, or bioelectricity. Resource biorecovery thus supports sustainability goals by reinjecting products into the circular economy.

For instance, the value-added bioprocessing of fish waste produces numerous bioproducts, which are: (1) pharmaceuticals such as proteins, jadomycin, collagen, lactic acid, glycerol, proteases, lipases, and collagenases; (2) nutraceuticals such

as omega-3, amino acids, fish oil, fatty acids, carotenoids, isoflavones, and lutein; (3) chemicals such as 1,2-propanediol and 1,3-propanediol, dihydroxy-acetone, and methanol; (4) biofuels such as biodiesel, bioethanol, and biohydrogen; and (5) further products such as fish meal and fish silage. On the other hand, the value-added bioprocessing of slaughtering waste produces the same above-mentioned products except that the intermediate product, in this case, is the tallow compared to fish oil as an intermediate product in the bioprocessing of fish waste.

Furthermore, there are several potential uses of fish waste in the production of further pharmaceuticals such as chymotrypsin, pepsin, enzyme inhibitors, anticoagulants, insulin, nucleic acid, nucleotides, protamine, and proteolytic enzymes. Besides, several biochemicals can be produced such as bile salts, glue, gelatin, leather, and pearl essence.

## **5. Industrial ecology and eco-efficiency**

The industrial ecology is the design of industrial infrastructures as a series of interlocking manufactured ecosystems in order to maximize the energy use efficiency, reduce the costs, reduce the environmental problems, identify new value-added products, and maximize the resources use efficiency, which leads to the sustainability. An important key issue is the interpretation of the insinuation of employing the ecological models to restore the agro-industrial systems, through applying the concepts of eco-design and eco-efficiency leading to a cleaner production allowing to reach a zero-waste and zero-emission system. This requires inevitably conducting environmental impact assessment and life cycle analysis of the agro-industrial processes and products. On the other hand, the aim of eco-efficiency is to boost the values of products by optimizing the utilization of resources and minimizing the negative environmental impacts by incorporating both efficiency and innovation into the industrial process without expensive pollution control techniques.

## **6. Cleaner production**

The cleaner production procedure is the first step in the implementation of the concept of industrial ecology. The procedure includes: (1) the examination of production systems in terms of the efficient use of natural resources and the efficient use of energy, and (2) the utilization of life cycle analyses method to evaluate the products and the agro-industrial processes in order to minimize waste and pollution as well as reduce costs and identify new prospects such as new products and employment opportunities.

Regarding the products, the procedure aims at reducing the negative impacts throughout the entire life cycle of the product from cradle to grave, i.e., from design to final disposal. Regarding the agro-industrial processes, cleaner production aims at (1) efficient use of raw materials, (2) efficient use of energy, and (3) reduction of emissions and wastes. An important key issue is to incorporate environmental concerns into designing processes and delivering the products.

## **7. Integrated bioindustrial systems and biorefinery**

The concept of integrated bioindustrial systems aims at (a) designing circular production and consumption systems leading to maximize the efficiencies of resources

and energy uses and to allow the required energy and resources for forthcoming development, (2) forming a further ecologically sound and healthy environment through less waste is generated at each level of production and the conversion of waste into value-added products, and (3) emphasizing the socio-economic development through creating new employment opportunities and ground-breaking technologies and new products.

The biorefinery is the cornerstone of the integrated bioindustrial systems, where a biorefinery is a production plant that combines bioconversion processes biomass and devices such as bioreactors to generate biofuels, electrical energy, heat energy, and value-added biochemicals from biomass. The International Energy Agency, Bioenergy Task 42 on Biorefineries, has defined biorefining as the sustainable processing of biomass into a spectrum of bio-based products (food, feed, chemicals, materials) and bioenergy (biofuels, power, and/or heat). Considering that biomass is all organic matters -except fossil fuels- such as forest materials, agricultural crops residues, livestock manure, organic fraction of municipal solid wastes, fish processing wastes, and food processing wastes [4].

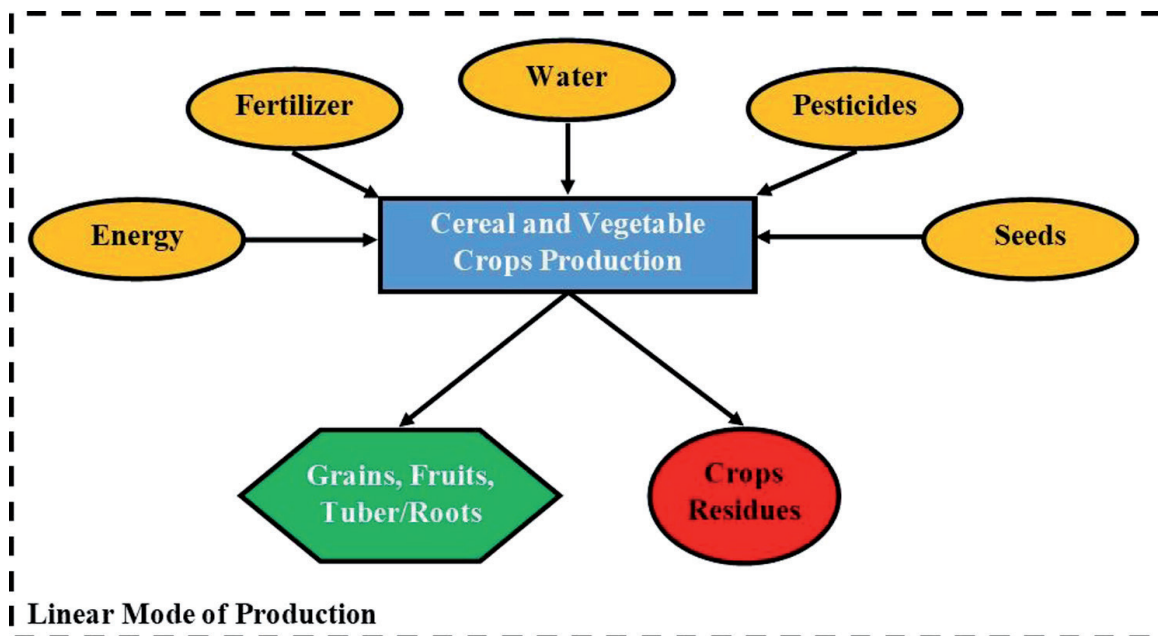
The concept of biorefinery has several objectives: (1) maximizing energy use efficiency, (2) maximizing resource use efficiency, (3) minimizing environmental problems, (4) creating new value-added products, and (5) creating new employment opportunities. However, there are some critical concerns such as the competing uses of materials, market demands, and production costs.

The biorefinery has several advantages: (1) through producing numerous products, a biorefinery takes advantage of the numerous components in biomass and their intermediates then intensifying the value derived from the biomass, and (2) through producing various low-volume, nevertheless high-value, chemical products such as nutraceuticals and pharmaceuticals and a low-value, nonetheless high-volume liquid transportation fuel such as biodiesel and bioethanol, (3) meanwhile generating electrical energy and heat, through combined heat and power (CHP) plant, and (4) creating new high value-added products maximizes the feasibility, where the high-volume fuel's production meet the energy demands, and the electricity and heat production minimizes the energy costs and decreases the greenhouse gas (GHG) emissions.

However, the subsequent concerns should be considered: (1) risk of excessive consumption of edible crops, (2) risk of deterioration of organic and mineral content of soils, (3) risk of excessive utilization of chemical fertilizers and pesticides to advance the production levels, (4) risk of competition between food and biorefinery, and (5) risk of deforestation.

The following is an approach to transform the present agricultural systems (beef, dairy, and poultry farms as well as cereals and vegetable crops production) and agro-industrial systems (ethanol industry and fish industry) into integrated bioindustrial systems by altering their linear mode of production into a circular mode of production to create a coherent bioeconomy, where the bioeconomy includes the conversion of renewable bioresources and waste streams into value-added bioproducts, such as food, feed, pharmaceuticals, nutraceuticals, biomaterials, biochemicals, biofuels, and bioenergy.

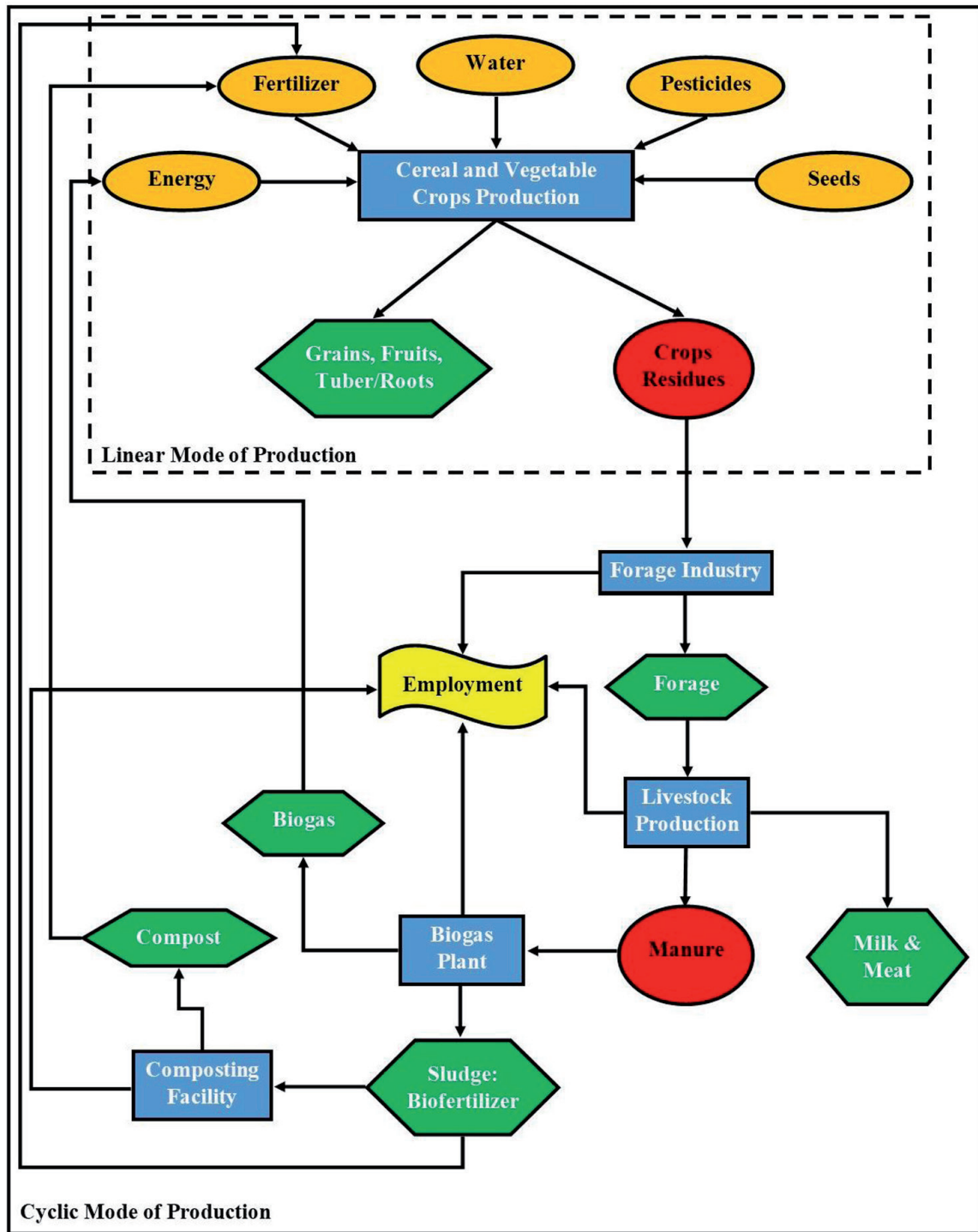
Cereal and vegetable production encompasses the utilization of several inputs such as water, fertilizers, pesticides, seeds, and energy. The products are grains, fruits, and tuber/roots. However, the waste is agricultural crops residues (**Figure 1**). The concept of bioeconomy is to use the output i.e., waste, of an industry or production system as an input i.e., feedstock, in another new industry. Therefore, this waste is planned to be used as feedstock for a new forage industry, where the produced forages are used



**Figure 1.** Linear mode of cereal and vegetable crops production (the orange oval designates the input, the blue rectangle designates the industry, the green hexagon designates the product, and the red circle designates the waste).

for feeding livestock in a new livestock production system that produces milk and meat. However, this industry generates animal waste i.e., manure, which is planned to be used as feedstock for a new biogas plant that produces biogas that fuels the cereal and vegetable crops production system. Besides, the generated sludge is used as a biofertilizer within the crops production system. Part of the generated sludge is used in a new compost facility and the produced compost is used within the crops production system as a biofertilizer. An important key issue is that 4 new industries were established and, therefore, 5 new products were produced, which are considered as economic development. It should be noticed that the core of all these newly planned industries and facilities, which were integrated with the crops production system, is creating new employment opportunities, which is considered as social development. Furthermore, these integrated bioindustrial systems have zero-waste, zero-emission, and efficient resources and energy use, which are considered as environmental development (**Figure 2**).

Beef and dairy production encompass the utilization of several inputs such as water, forages, and energy. The products are milk and meat. However, the wastes are slaughter waste, manure, and whey (**Figure 3**). The concept of bioeconomy is to use the output i.e., waste, of an industry or production system as an input i.e., feedstock, in another new industry. Therefore, the slaughter waste is used as feedstock in a biorefinery to produce biofuels, biochemicals, pharmaceuticals, and nutraceuticals. Additionally, manure and whey are planned to be used as feedstock for a new biogas plant, where the produced biogas is used for fueling the beef and dairy production system. The biogas plant generates sludge, which is used as biofertilizer for a new crops production system that produces grains and tuber/roots. Besides, the generated crop residues are used as feedstock for the forage industry, which produces forages for beef and dairy production. Part of the generated crops residues is used in a new compost facility and the produced compost is used in fertilizing the crops production as biofertilizer. An important key issue is that 5 new industries were established and, therefore, 9 new products were produced, which are considered as economic development. It should be noticed that the

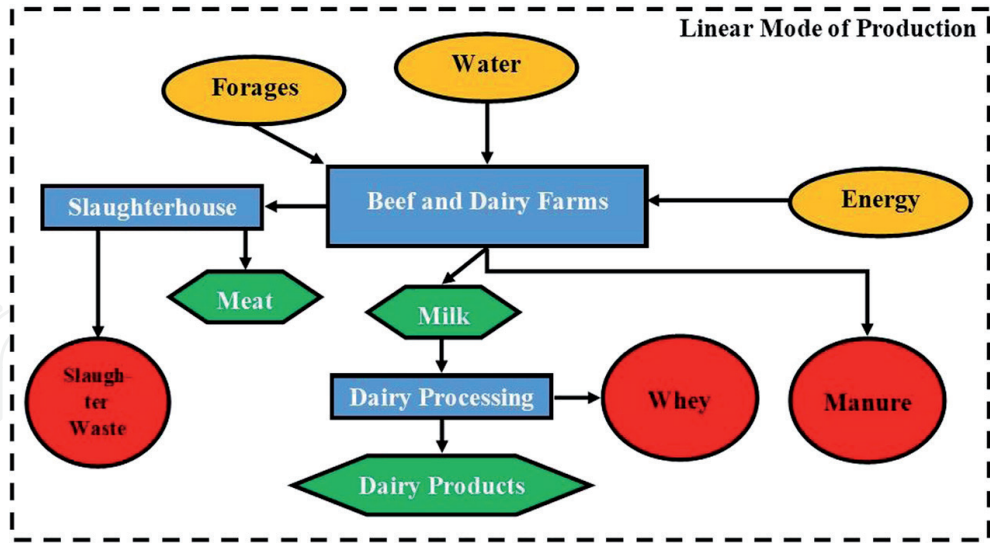


**Figure 2.** Cyclic mode of cereal and vegetable crops production through integrated bioindustrial systems (the orange oval designates the input, the blue rectangle designates the industry, the green hexagon designates the product, the red circle designates the waste, and the yellow wave designates the employment opportunity).

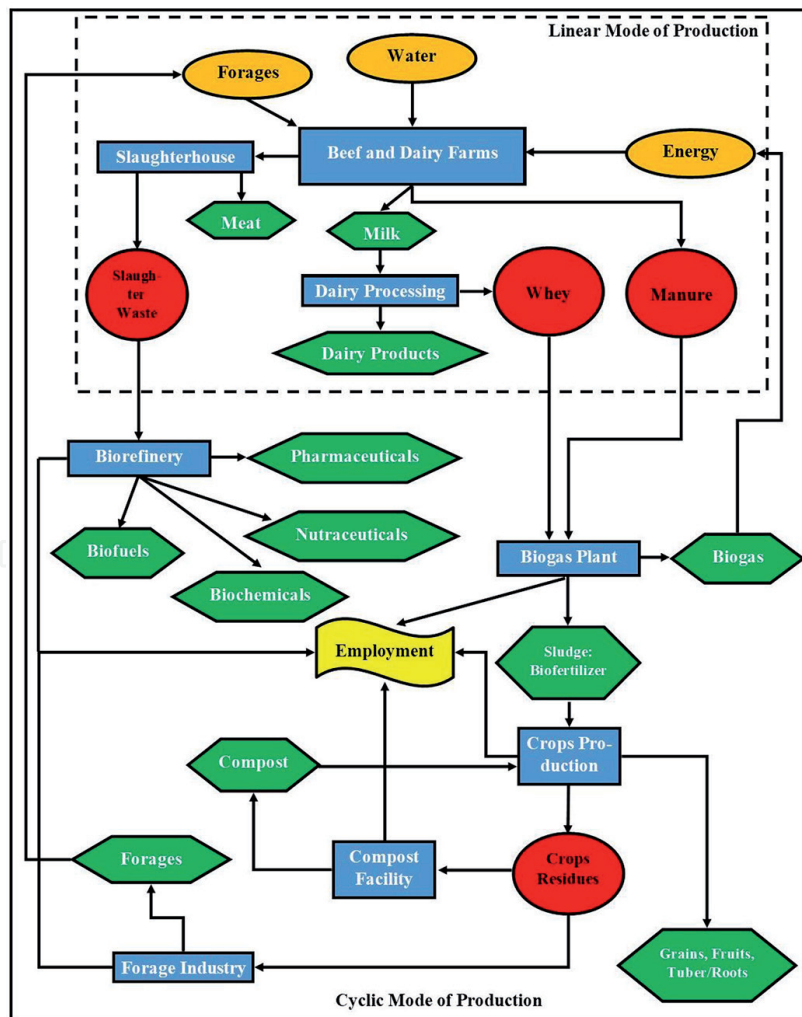
core of all these newly planned industries and facilities, which were integrated with the beef and dairy production system, is creating new employment opportunities, which is considered as social development. Furthermore, these integrated bioindustrial systems have zero-waste, zero-emission, and efficient resources and energy use, which are considered as environmental development (**Figure 4**).

The poultry industry encompasses the utilization of several inputs such as water, forages, and energy. The products are meat and eggs. However, the wastes

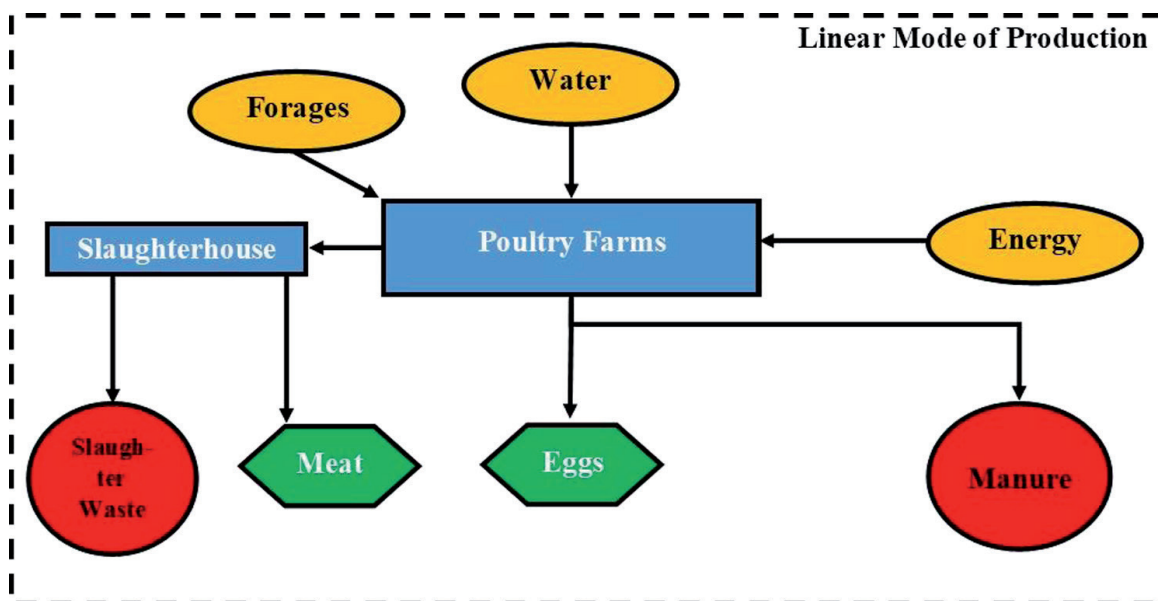




**Figure 3.** Linear mode of beef and dairy production (the orange oval designates the input, the blue rectangle designates the industry, the green hexagon designates the product, and the red circle designates the waste).



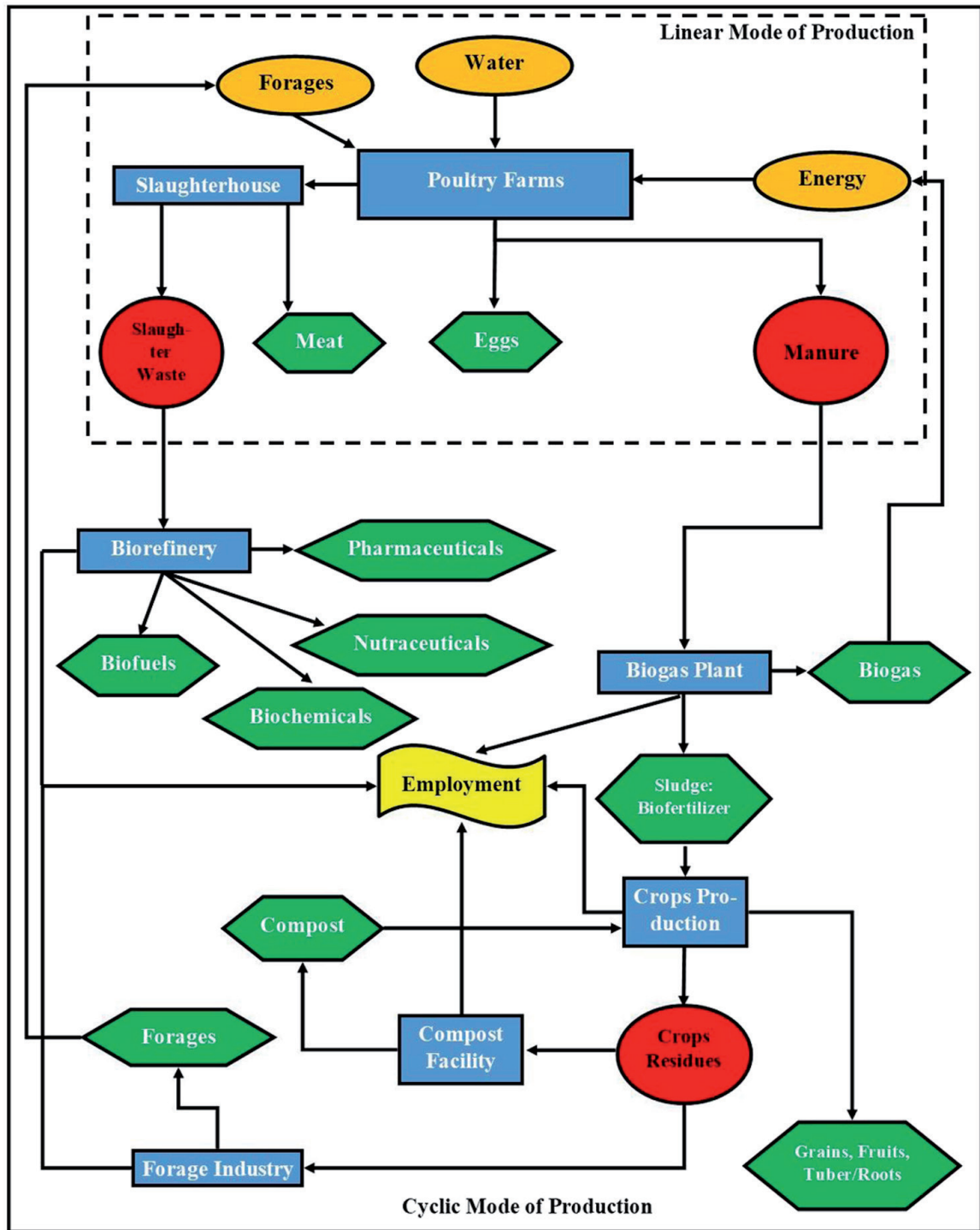
**Figure 4.** Cyclic mode of beef and dairy production through integrated bioindustrial systems (the orange oval designates the input, the blue rectangle designates the industry, the green hexagon designates the product, the red circle designates the waste, and the yellow wave designates the employment opportunity).



**Figure 5.** Linear mode of poultry production (the orange oval designates the input, the blue rectangle designates the industry, the green hexagon designates the product, and the red circle designates the waste).

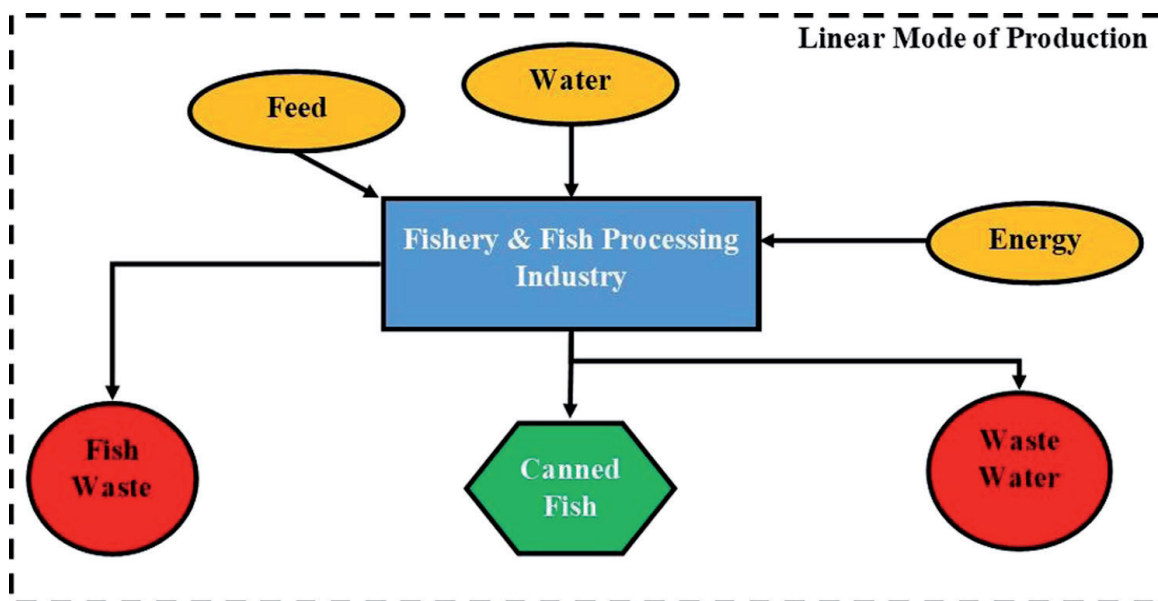
are slaughter waste and manure (**Figure 5**). The concept of bioeconomy is to use the output i.e., waste, of an industry or production system as an input i.e., feedstock, in another new industry. Therefore, the slaughter waste is used as feedstock in a biorefinery to produce biofuels, biochemicals, pharmaceuticals, and nutraceuticals. Additionally, poultry manure is planned to be used as feedstock for a new biogas plant, where the produced biogas is used for fueling the poultry production system. The biogas plant generates sludge, which is used as biofertilizer for a new crops production system that produces grains and tuber/roots. Besides, the generated crop residues are used as feedstock for the forage industry which produces forages for the poultry farms. Part of the generated crops residues is used in a new compost facility and the produced compost is used in fertilizing the crops production as biofertilizer. An important key issue is that 5 new industries were established and, therefore, 9 new products were produced, which are considered as economic development. It should be noticed that the core of all these newly planned industries and facilities, which were integrated with the poultry production system, is creating new employment opportunities which is considered as social development. Furthermore, these integrated bioindustrial systems have zero-waste, zero-emission, and efficient resources and energy use, which are considered as environmental development (**Figure 6**).

The fish processing industry encompasses the utilization of several inputs such as water, feed, and energy. The product is canned fish. However, the wastes are a large amount of fish waste and a large amount of wastewater (**Figure 7**). The concept of bioeconomy is to use the output i.e., waste, of an industry or production system as an input i.e., feedstock, in another new industry. Therefore, a large amount of wastewater is planned to be used as feedstock for a new wastewater treatment plant, where the treated water is used as input water in the fish processing industry. Further, this plant generates sludge, which is planned to be used as feedstock for a new biogas plant that produces biogas that fuels the fish processing industry. Besides, the generated sludge is considered a new product as biofertilizer. On the other hand, the large amount of fish waste is used as feedstock for a new biorefinery that produces fish meal and fish silage, pharmaceuticals (proteins, jadomycin, collagen, lactic acid,



**Figure 6.** Cyclic mode of poultry production through integrated bioindustrial systems (the orange oval designates the input, the blue rectangle designates the industry, the green hexagon designates the product, the red circle designates the waste, and the yellow wave designates the employment opportunity).

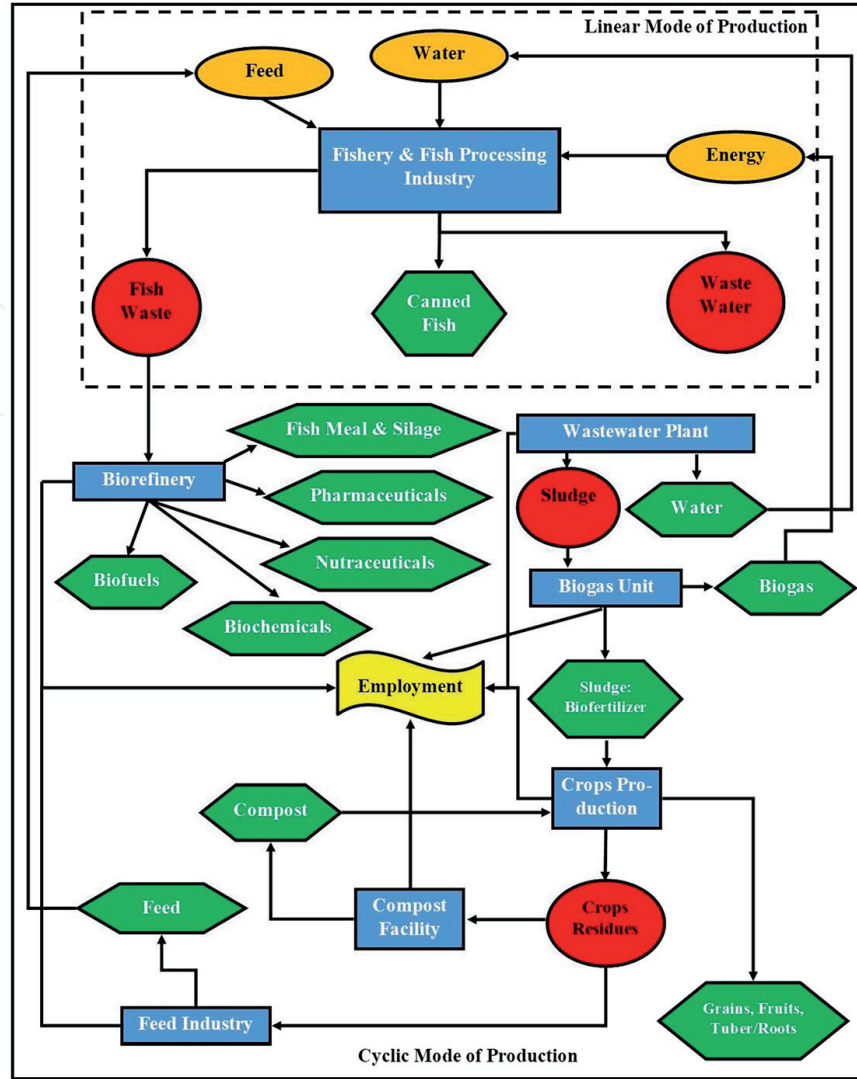
glycerol, proteases, lipases, and collagenases), nutraceuticals (omega-3, amino acids, fish oil, fatty acids, carotenoids, isoflavones, and lutein), chemicals (1,2-propanediol and 1,3-propanediol, dihydroxy-acetone, and methanol), biofuels (biodiesel, bioethanol, and biohydrogen). An important key issue is that 6 new industries were established and, therefore, a multitude of new products were produced, which are considered as economic development. It should be noticed that the core of all these



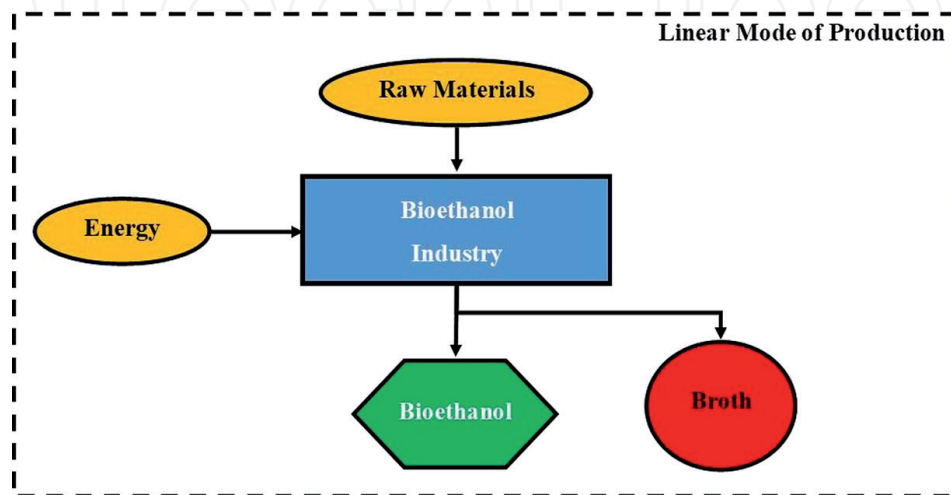
**Figure 7.** Linear mode of fish industry (the orange oval designates the input, the blue rectangle designates the industry, the green hexagon designates the product, and the red circle designates the waste).

newly planned industries and facilities, which were integrated with the fish processing industry, is creating new employment opportunities, which is considered as social development. Furthermore, these integrated bioindustrial systems have zero-waste, zero-emission, and efficient resources and energy use, which are considered as environmental development (**Figure 8**).

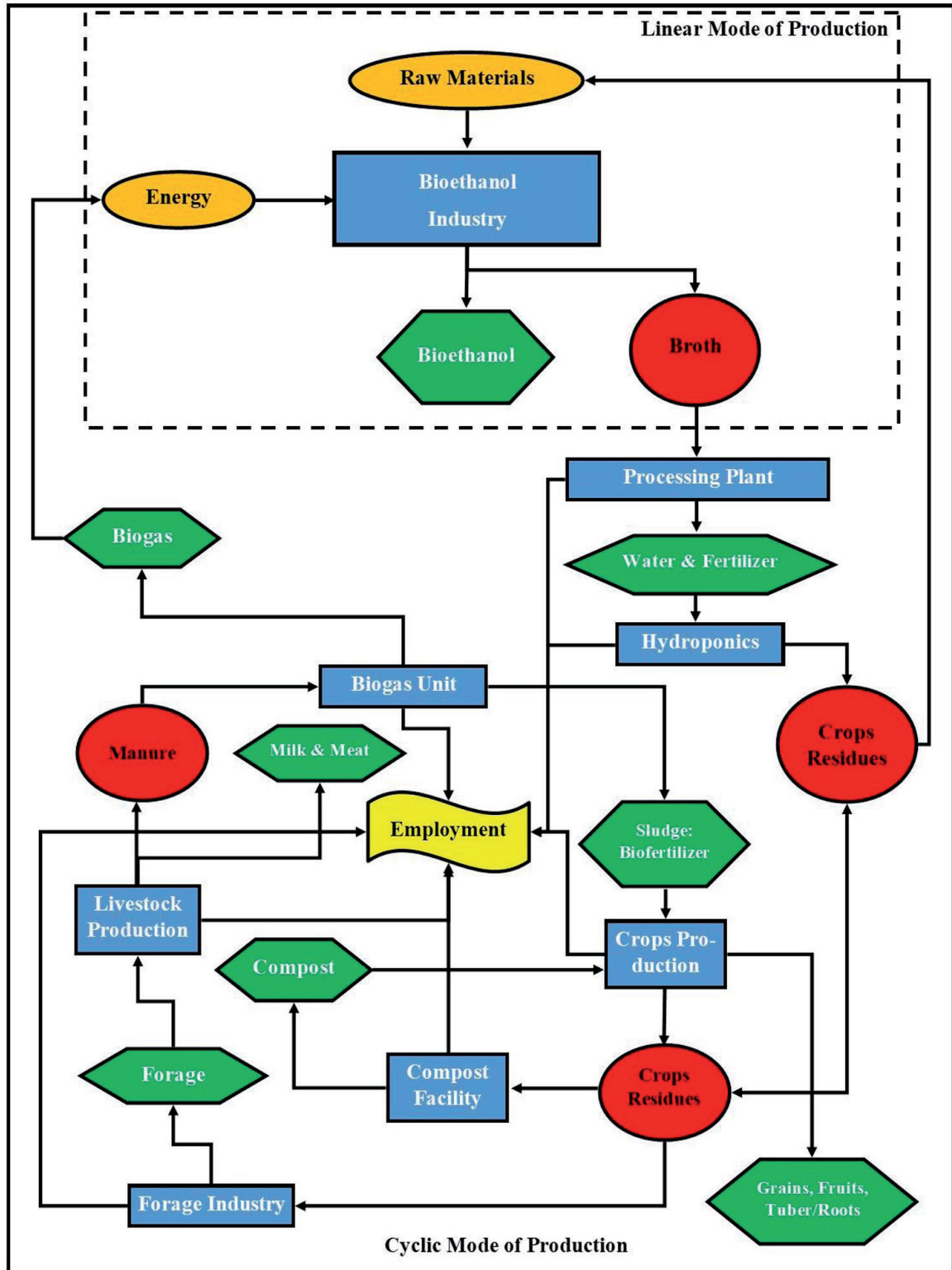
The bioethanol industry encompasses the utilization of inputs such as energy and raw cellulosic materials. The product is bioethanol. However, the waste is broth (**Figure 9**). The concept of bioeconomy is to use the output i.e., waste, of an industry or production system as an input i.e., feedstock, in another new industry. Therefore, this waste is planned to be used as feedstock for a new processing industry that produces wastewater and biofertilizer, where these products are used in a new hydroponics system that produces biowastes (crops residues). These wastes i.e., crop residues, are planned to be used as feedstock for a new forage industry that produces forages for a new livestock production system. However, this industry generates animal waste i.e., manure, which is planned to be as feedstock for a new biogas plant, which produces biogas that fuels the bioethanol industry. Besides, the generated sludge is used as biofertilizer for a new crops production system. Part of the generated sludge is used in a new compost facility and the produced compost is used within the crops production system as biofertilizer. The produced crops residues from the new crops production system as feedstock in a new compost industry, which produces a biofertilizer. An important key issue is that 6 new industries were established and, therefore, 7 new products were produced which are considered as economic development. It should be noticed that the core of all these newly planned industries and facilities, which were integrated with the bioethanol industry, is creating new employment opportunities, which is considered as social development. Furthermore, these integrated bioindustrial systems have zero-waste, zero-emission, and efficient resources and energy use, which are considered as environmental development (**Figure 10**).



**Figure 8.** Cyclic mode of fish industry through integrated bioindustrial systems (the orange oval designates the input, the blue rectangle designates the industry, the green hexagon designates the product, the red circle designates the waste, and the yellow wave designates the employment opportunity).



**Figure 9.** Linear mode of bioethanol industry (the orange oval designates the input, the blue rectangle designates the industry, the green hexagon designates the product, and the red circle designates the waste).



**Figure 10.** Cyclic mode of bioethanol industry through integrated bioindustrial systems (the orange oval designates the input, the blue rectangle designates the industry, the green hexagon designates the product, the red circle designates the waste, and the yellow wave designates the employment).

## 8. Digitalization in the bioeconomy

Digitalization is essential to the advancement of the bioeconomy. Digitalization is promoting intelligibility throughout the value chains and facilitates to scrutinize the conformity with afforded standards. Digitalization modifies the route for expanding

traditional bioeconomy and is converting the bioeconomy into a progressively multi and interdisciplinary proficient sector.

The digital revolution in the bioeconomy has 3 unique aspects: (1) the utilization of digital tools as a tool for monitoring. For instance, real-time monitoring of farming operations such as crops, and livestock can provide timely and feasibly added value. Likewise, in forestry, monitoring provides added value by processing data, optimizing the conservation and use of forest products, (2) data aid the development of value chains in terms of reusing, recycling, and repairing. Digitalization provides data analysis for biorefineries or bioindustry can assist in identifying new products evolving from what was formerly considered as biowaste, and (3) data-driven at its core, biosciences are growing precipitously owing to the expanding repository of information. Its application can be observed through a wide range of products and services such as the usage of genomes for therapeutics, personalized medicine, and pharmaceuticals. It can be noticed as well in the advancement of biochemicals as alternatives for petrochemicals.

Digital tools offer a variety of prospects within the traditional bioeconomy sectors such as farming, fisheries, and forestry. For farmers, the ability to track and monitor their livestock and crops boosts daily operations and grants for accurate development. There are also prospects for improved precision, as data is pooled promptly throughout the value chain from forage to dairies, slaughterhouses, products manufacturing, marketing, and consumption. Within the forestry industry, digital tools can be used for monitoring, forecasting, and management of forests.

Digitalization is encouraging practices innovation by boosting both supply and value chains in the circular bio-based economy. Thus, digitalization is able to play a role as a facilitator of circular bioeconomy procedures by for instance altering business patterns. Manipulating data to detect gaps for improving manufacture, or even to pinpoint how to help obtain value from both current production lines and bio-based waste streams are components of this development. At this point, streams of the circular bio-based economy, for instance, biowaste streams, are employed in different approaches since the data-driven procedures are strengthening the bioeconomy.

Digitalization is a component of the circular bioeconomy, where the bioindustrial systems are aiming at applying the circular economy standards that broaden the lifecycle of biowaste by recycling them as feedstock for bioenergy generation. Digitalization, smart algorithms, and advanced computer modeling guarantee resource boosting in the bioindustrial systems, raise the value of green production and are a factor in energy trade-off. Applications include open innovation platforms providing data access, which is open for research and development (R&D) as well as business. Digitalization can be used to create higher-value products in the circular bio-based economy. Digital tools can be implemented for making new value-added bioproducts. For instance, the production of novel and high-value bioproducts using existing bioresources.

Big data is cornerstone in developing biosciences. In the health sector, for instance, big data is accelerating encouraging results in biomedical research. At this point, the quick leap of data-driven analysis is anticipated to reach a higher level of personalized medicine and pharmaceuticals. High levels of digitalization such as blockchain and artificial intelligence coupled with its application in, for instance, agriculture, aquaculture, and forestry, brand-new bioproducts, and recycling of by-products are projected to occur. The intersecting role of data for R&D as well as an invention in bioeconomy is applied in contemporary waste management such as the use of bacteria in biowaste degradation.

Data analysis is crucial for a profitable green transition. Numerous biorefineries implement data in fostering the applications of biosciences in utilizing, for instance, forest by-products. Biomaterials such as lignin were found to be valuable feedstock in the production of food, feed, and adhesives. Technologies such as pyrolysis use biological but inedible feedstock and produce liquid bio-oils. The bio-oil is consistent with the current fossil oil infrastructure, and thus fills one of the gaps arising between the bio-based economy and the petroleum-based economy. The rapid leap of data analysis is able to accelerate finding solutions for global challenges.

A digital transformation is in progress in the circular bio-based economy. Guaranteeing that rural communities realize the profits of this transformation necessitates a re-outlining of the discussion to emphasize not only the digitalization itself but the growth potential it offers. This perspective is comprehensive and involves the formation of innovative bioproducts, services, and bioindustries. While based on rural resources, these opportunities necessitate additional collaboration that reinforces rural–urban relationships. The digital revolution of the circular bio-based economy likewise retains the capability to carry out businesses in conventional circular bio-based economy sectors attracting a wider cross-section of communities. This leads to create new employment opportunities for rural communities.

Generally, the applications of digital tools include prototyping electronic boards, internet of things (IoT) platforms, software, and cellphone applications to control the operation of the bioproducts production systems as well as compute the input materials and energy on the one hand and the output materials and energy on the other hand. Similar applications include livestock farming, for example detecting the activity and health of the animals and informing the animal owner. Further applications include operating the cooling/heating systems based on detected indoor conditions in greenhouses and livestock barns. Another application is in precision farming to control the farming operations conducted by agricultural machinery connected to satellites. Further application is that digital tools can control the interoperability of agricultural systems e.g., control the soil-based sensors to be consistent with the tractor. Additionally, the role of mechatronics is highly foreseen in these applications. Finally, a further application is the use of QR-codes (Quick Response code) to boost comprehensibility across the value chain. For instance, QR-codes are used to track livestock, allowing consumers to trace the food they consume from its source through the route to the retailer. Several applications in this context were developed as cell phone applications [5] and desktop software [6–9].

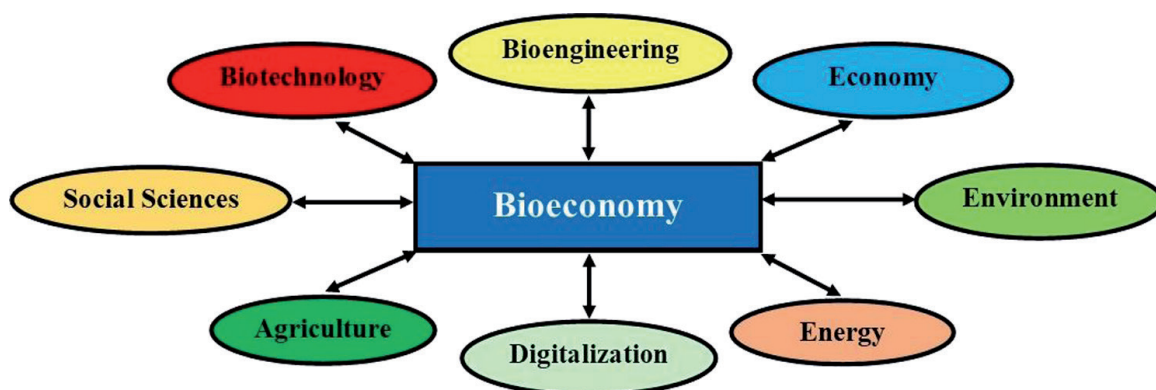
## **9. Recent advancements**

Nanotechnology and laser radiation have been implemented in the production process of several bioproducts [10–16]. Besides, the implementation of life cycle analysis (LCA) and environmental impact assessment (EIA) methodologies are of high importance to analyze the life cycle of bioproducts and to determine the environmental impact of the production processes [17–21]. A key issue is to conduct a techno-economic assessment (TEA) of the used technologies in the production process [22].

## **10. Summary and conclusions**

This study provides an approach to convert the present agricultural systems (beef, dairy, and poultry farms as well as cereals and vegetable crops production)





**Figure 11.**  
The fields of science related to bioeconomy.

and agro-industrial systems (ethanol industry and fish industry) into integrated bioindustrial systems and biorefineries through amending their linear mode of production into a circular mode of production to develop a sustainable bioeconomy. This development includes the bioconversion of biowaste streams from the existing agricultural and agro-industrial systems into value-added bioproducts, such as food, feed, pharmaceuticals, nutraceuticals, biomaterials, biochemicals, biofuels, and bioenergy where these novel bioproducts are considered as economic development. Whereas the core of the planned bioindustries is creating new employment opportunities, which is considered as social development. Furthermore, these integrated bioindustrial systems have zero-waste, zero-emission, and efficient resources and energy use, which are considered as environmental development. An important key issue is that digitalization guarantees resource boosting in the bioindustrial systems, where applications include the development of electronic boards, internet of things (IoT) platforms, software, and cellphone applications for monitoring and controlling the operations, computing input and output materials, and energy, and fostering comprehensibility across the value chain. **Figure 11** summarizes the fields of science related to bioeconomy.

## Author details

Mohamed Samer  
Faculty of Agriculture, Department of Agricultural Engineering, Biosystems  
Engineering Group, Cairo University, Giza, Egypt

\*Address all correspondence to: msamer@agr.cu.edu.eg

## IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

## References

- [1] Ronzon T, Lusser M, Landa L, M'Barek R, Klinkenberg M, Sanchez Lopez J, et al. Bioeconomy Report 2016. JRC Scientific and Policy Report. EUR 28468 EN. Publications Office of the European Union, Luxembourg; 2017
- [2] Available from: <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52015DC0614&from=ES>
- [3] Available from: <https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32009L0028>
- [4] International Energy Agency. 2009. Biorefineries: Adding Value to the Sustainable Utilisation of Biomass. Bioenergy Task 42 on Biorefineries
- [5] Samer M, Helmy K, Morsy S, Assal T, Amin Y, Mohamed S, et al. Cellphone application for computing biogas, methane and electrical energy production from different agricultural wastes. *Computers and Electronics in Agriculture*. 2019;**163**:104873
- [6] Samer M, Hatem M, Grimm H, Doluschitz R, Jungbluth T. A software for planning loose yards and designing concrete constructions for dairy farms in arid and semi-arid zones. *Emirates Journal of Food and Agriculture*. 2013;**25**(3):238-249
- [7] Samer M, Hatem M, Grimm H, Doluschitz R, Jungbluth T. An expert system for planning and designing dairy farms in hot climates. *Agricultural Engineering International: CIGR Journal*. 2012;**14**(1):1-15
- [8] Samer M, Loebstin C, von Bobrutzki K, Fiedler M, Ammon C, Berg W, et al. A computer program for monitoring and controlling ultrasonic anemometers for aerodynamic measurements in animal buildings. *Computers and Electronics in Agriculture*. 2011;**79**(1):1-12
- [9] Samer M. A software program for planning and designing biogas plants. *Transactions of the ASABE*. 2010;**53**(4):1277-1285
- [10] Attia YA, Samer M, Moselhy MA, Arisha AH, Abdelqader AA, Abdelsalam E. Influence of laser photoactivated graphitic carbon nitride nanosheets and nickel nanoparticles on purple non-sulfur bacteria for biohydrogen production from biomass. *Journal of Cleaner Production*. 2021;**299**:126898. DOI: 10.1016/j.jclepro.2021.126898
- [11] Abdelsalam EM, El-Hussein A, Samer M. Photobiostimulation of anaerobic digestion by laser irradiation and photocatalytic effects of trace metals and nanomaterials on biogas production. *International Journal of Energy Research*. 2021;**45**:141-150
- [12] Samer M, Abdelsalam EM, Mohamed S, Elsayed H, Attia YA. Impact of photoactivated cobalt oxide nanoparticles addition on manure and whey for biogas production through dry anaerobic co-digestion. *Environment, Development and Sustainability*. 2021;**23**:14683-14696
- [13] Abdelsalam EM, Samer M. Biostimulation of anaerobic digestion using nanomaterials for increasing biogas production. *Reviews in Environmental Science and Bio/Technology*. 2019;**18**(3):525-541
- [14] Abdelsalam E, Samer M, Attia Y, Abdel-Hadi MA, Hassan HE, Badr Y. Effects of laser irradiation and

Ni nanoparticles on biogas production from anaerobic digestion of slurry. *Waste and Biomass Valorization*. 2019;**10**(11):3251-3262

[15] Abdelsalam E, Samer M, Abdel-Hadi MA, Hassan HE, Badr Y. Influence of laser irradiation on rumen fluid for biogas production from dairy manure. *Energy*. 2018;**163**:404-415

[16] Attia YA, Kobeasy MI, Samer M. Evaluation of magnetic nanoparticles influence on hyaluronic acid production from *Streptococcus equi*. *Carbohydrate Polymers*. 2018;**192**:135-142

[17] Samer M, Hijazi O, Abdelsalam EM, El-Hussein A, Attia YA, Yacoub IH, et al. Life cycle assessment of using laser treatment and nanomaterials to produce biogas through anaerobic digestion of slurry. *Environment, Development and Sustainability*. 2021. DOI: 10.1007/s10668-021-01264-9

[18] Ioannou-Ttofa L, Foteinis S, Moustafa AS, Abdelsalam E, Samer M, Fatta-Kassinos D. Life cycle assessment of household biogas production in Egypt: Influence of digester volume, biogas leakages, and digestate valorization as biofertilizer. *Journal of Cleaner Production*. 2021;**286**:125468

[19] Hijazi O, Abdelsalam E, Samer M, Attia YA, Amer BMA, Amer MA, et al. Life cycle assessment of the use of nanomaterials in biogas production from anaerobic digestion of manure. *Renewable Energy*. 2020;**148**:417-424

[20] Hijazi O, Abdelsalam E, Samer M, Amer BMA, Yacoub IH, Moselhy MA, et al. Environmental impacts concerning the addition of trace metals in the process of biogas production from anaerobic digestion of slurry. *Journal of Cleaner Production*. 2020;**243**:118593

[21] Abdelsalam E, Hijazi O, Samer M, Yacoub IH, Ali AS, Ahmed RH, et al. Life cycle assessment of the use of laser radiation in biogas production from anaerobic digestion of manure. *Renewable Energy*. 2019;**142**:130-136

[22] Samer M, Abdelaziz S, Refai M, Abdelsalam E. Techno-economic assessment of dry fermentation in household biogas units through co-digestion of manure and agricultural crop residues in Egypt. *Renewable Energy*. 2020;**149**:226-234