

AGRICULTURE WASTE MANAGEMENT AND BIORESOURCE

THE CIRCULAR ECONOMY PERSPECTIVE

EDITED BY

SURUCHI SINGH | PARDEEP SINGH

ANU SHARMA | MOHARANA CHOUDHURY



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Agriculture Waste Management and Bioresource

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The Circular Economy Perspective

Edited by

Suruchi Singh

Sunbeam College for Women, Varanasi, India

Pardeep Singh

*Department of Environmental Studies, PGDAV College,
University of Delhi, New Delhi, India*

Anu Sharma

*Department of Environmental Sciences,
University of Jammu, India*

Moharana Choudhury

*Environmental Research and Management Division,
Voice of Environment (VoE) Guwahati,
Assam, India*

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List of Contributors

Sangita Agarwal

Department of Applied Science
RCC Institute of Information Technology
Kolkata, West Bengal, India

Md. Abdullah Aziz

Agricultural Statistics Division
Bangladesh Rice Research Institute (BRRI)
Gazipur, Bangladesh

Hangma Boro

Department of Botany
Rangapara College
Rangapara, Assam, India

Ratan Chowdhury

Department of Botany
Rangapara College
Rangapara, Assam, India

Papori Dahutia

Department of Physics
Dibrugarh University
Dibrugarh, Assam, India

Soumendra Darbar

Faculty Council of Science
Jadavpur University
Kolkata, West Bengal
India; Research and Development Division
Dey's Medical Stores (Mfg.) Ltd., Kolkata
West Bengal, India

Tathagata Deb

Department of Applied Science
RCC Institute of Information Technology
Kolkata, West Bengal, India

Sukhendu Dey

Department of Environmental Science
The University of Burdwan
Burdwan, West Bengal, India

Joystu Dutta

Department of Environmental Science
University Teaching Department
Sant Gahira Guru University
Ambikapur, Chhattisgarh, India

Joysurya Dutta

Symbiosis Institute of Operations
Management (SIOM), Nashik, Maharashtra

Apurba Ratan Ghosh

Department of Environmental Science
The University of Burdwan
Burdwan, West Bengal, India

Navamallika Gogoi

Department of Chemistry
Arunachal University of Studies
Namsai, Arunachal Pradesh, India

Nirmali Gogoi

Department of Environmental Science
Tezpur University
Tezpur, Assam, India

Anwesha Gohain

Department of Botany
Arunachal University of Studies
Namsai, Arunachal Pradesh, India

Avinash Pratap Gupta

Department of Environmental Science
Sant Gahira Guru University
Sarguja, Chhattisgarh, India

Ravindra Pratap Singh

Central Public Works Department
New Delhi, India

Sumi Handique

Department of Environmental Science
Tezpur University
Tezpur, Assam, India

R.Y. Hiranmai

School of Environment and Sustainable
Development
Central University of Gujarat
Gandhinagar, Gujarat, India

Md. Shahadat Hossain

Training Division
Bangladesh Rice Research Institute (BRRI)
Gazipur, Bangladesh

Asha Humbal

School of Environment and Sustainable
Development
Central University of Gujarat
Gandhinagar, Gujarat, India

Rani Jha

Department of Chemistry
Arunachal University of Studies
Namsai, Arunachal Pradesh, India

Sanjib Kalita

Department of Botany
Gauhati University
Guwahati, Assam, India

Mohammad Ashik Iqbal Khan

Plant Pathology Division
Bangladesh Rice Research Institute (BRRI)
Gazipur, Bangladesh

Vinod Kumar

Algal Research and Bioenergy Lab
Department of Chemistry
Uttaranchal University
Dehradun, Uttarakhand, India;
Department of Environmental Monitoring
and Forecasting
Ecological Faculty
RUDN University
Moscow, Russia

A.K. Mall

Division of Crop Improvement
ICAR-Indian Institute of Sugarcane
Research
Lucknow, Uttar Pradesh, India

Varucha Misra

Division of Crop Improvement
ICAR-Indian Institute of Sugarcane
Research
Lucknow, Uttar Pradesh, India

Manisha Nanda

Department of Biotechnology
Dolphin (P.G.) Institute of Biomedical and
Natural Sciences
Dehradun, Uttarakhand, India

Ajay Neeraj

School of Environment and Sustainable
Development
Central University of Gujarat
Gandhinagar, Gujarat, India

Amrita Kumari Panda

Department of Biotechnology
Sant Gahira Guru Vishwavidyalaya
Sarguja, Ambikapur, Chhattisgarh, India

A.D. Pathak

Division of Crop Improvement
ICAR-Indian Institute of Sugarcane
Research
Lucknow, Uttar Pradesh, India

Bhawana Pathak

School of Environment and Sustainable
Development
Central University of Gujarat
Gandhinagar, Gujarat, India

Md. Khairul Quais

Rice Farming Systems Division
Bangladesh Rice Research Institute (BRRI)
Gazipur, Bangladesh

Farhana Rahman

University of Technology Sydney (UTS)
Sydney, NSW, Australia

Vishal Rajput

Himalayan School of Bio-sciences
Swami Rama Himalayan University
Dehradun, Uttarakhand, India

Priyabrata Roy

Department of Molecular Biology and
Biotechnology
University of Kalyani
Kalyani, West Bengal
India

Subham Roy

Department of Botany
Rangapara College
Rangapara, Assam, India

Ankita Saha

Department of Environmental Science
Tezpur University
Tezpur, Assam, India

Srimoyee Saha

Department of Life Science and
Biotechnology
Jadavpur University
Kolkata, West Bengal, India

Kundil Kumar Saikia

Department of Environmental Science
Tezpur University
Tezpur, Assam, India

Palas Samanta

Department of Environmental Science
Sukanta Mahavidyalaya
University of North Bengal
Dhupguri, West Bengal, India

Santeshwari Srivastava

Division of Crop Improvement
ICAR-Indian Institute of Sugarcane
Research
Lucknow, Uttar Pradesh, India

Biman Kumar Sarma

Department of Zoology, Rangapara College
Rangapara, Assam, India

Payal Sen

Independent Researcher
Chembur East
Mumbai, Maharashtra, India

Tirthankar Sen

Department of Biosciences and
Bioengineering
Indian Institute of Technology Guwahati
Guwahati, Assam, India

Tarakeshwar Senapati

Department of Environmental Science
Directorate of Distance Education
Vidyasagar University
Midnapore, West Bengal, India

Anu Sharma

Govt. SPMR College of Commerce
Constituent College of Cluster University
of Jammu
Jammu, Jammu and Kashmir (UT), India

Pradeep Kumar Tiwari

Independent Researcher
New Housing Board Colony
Shahdol, Madhya Pradesh, India

Prachi Upadhyay

Independent Researcher
Forest Research Institute (Deemed-to-be)
University
Dehradun, Uttarakhand, India

Monu Verma

Department of Environmental Engineering
The University of Seoul
Seoul, Republic of Korea

M.S. Vlaskin

Laboratory for Energy Accumulating
Materials
Joint Institute for High Temperatures of
the Russian Academy of Sciences
Moscow, Russia

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Agricultural Waste as a Resource: The Lesser Travelled Road to Sustainability

Avinash Pratap Gupta¹, Prachi Upadhyay², Tirthankar Sen³, and Joystu Dutta¹

¹ Department of Environmental Science, Sant Gahira Guru University, Sarguja, Chhattisgarh, India

² Forest Ecology and Environment Management Division, Forest Research Institute (Deemed-to-be) University, Dehradun, Uttarakhand, India

³ Department of Biosciences and Bioengineering, Indian Institute of Technology Guwahati, Guwahati, Assam, India

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1.1 Introduction

With the expansion of agricultural activities, the amount and type of wastes being produced from them have increased. As per the Organization for Economic Cooperation and Development and the Food and Agriculture Organization (OECD-FAO), 39.35 million tons of natural fibres are annually being obtained from plants by the farmers, which also contribute to waste production. China reportedly produces 56.2 million tons of

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agricultural wastes. The types of wastes and their amount are dependent on the country and their management (Nagalakshmaiah et al. 2016; Letcher and Vallerio 2019; Kamel et al. 2020). Agricultural wastes are basically the outputs that are not utilized in products or residues produced from the harvest/rearing and processing of raw agricultural products. Although many agricultural wastes contain substances of human value or benefit, it is mostly the case that the economic value of these processed substances is lower than the cost of collection, transportation, and processing of the feedstock. Therefore, wastes are generated due to the economic infeasibility of processing or reusing discarded agricultural by-products.

Agricultural wastes may be in the many forms like solids, slurries, or liquids and can have both plant and animal origins. For example, agricultural wastes encompass

- animal wastes such as manure, carcasses and bones;
- food processing wastes such as corn stalks, fruit peels cores pits pulp stems and seeds, twigs, spoiled fruits, sugarcane bagasse, and molasses;
- crop discards such as corn stalks, fruit/vegetable drops, culls, and pruning;
- toxic agricultural wastes such as pesticides, herbicides, herbicides, and antifungals.

The composition of agricultural wastes can be different from location to location and is dependent on the particulars of the point of origin like the agricultural activities carried out and the regional specialization. Interestingly, the challenges in waste management as well as the opportunities faced by a region because of the primary residues generated are also related to the regional specialization. For example, in locations specifically used for animal husbandry, vast quantities of organic matter rich in nitrogen and nutrient-rich waste materials are generated alongside repugnant odours, microbial contamination, and greenhouse gas (methane) emissions. Manure production is therefore among the most feasible waste management routes for these regions in comparison with the regions devoted to crop production where nutrients and the organic matter deplete because of the nutritional demands exerted by the growing crops on the soil (Gontard et al. 2018).

During the past several decades, significant scientific and technological advancements have resulted in a gradual increase of agricultural yield and productivity throughout the world. This, however, has also resulted in a steady increase in the quantity of waste from livestock, agricultural crop residues, and by-products of agro-industries. Although highly accurate estimates of agricultural waste production are rare, it is believed that agricultural waste contributes significantly to the global total waste production. Over a decade ago, the world was estimated to produce nearly 1000 million tons of waste from agriculture (Agamuthu 2009). Organic wastes have been documented to account for up to 80% of the total solid waste being produced in a farm (Brown and Root Environmental Consultancy Group 1997). In 2012, organic wastes accounted for more than half of the fresh waste of the harvested crops representing a potential of 90 Million Tons Oil Equivalent (MTOE) which was far higher than the energy potential of other wastes such as round wood, municipal wastes, and tertiary forest residues (Elbersen et al. 2012). This scenario is likely to worsen if proper interventions are not put in place.

In this modern age of industrialization and globalization, economic progress is heavily intertwined with non-renewable resource utilization which adversely impacts

environmental balance and biodiversity, jeopardizes global food security, and depletes our planet's non-renewable energy reserves (UNEP 2011). Agricultural waste can be transformed into economically valuable products, such as fertilizers, energy, and chemicals, by using specialized conversion processes. This is of critical importance so as to promote a sustainable bioeconomy and consequently decouple non-renewable resource utilization and economic progress from human well-being and environmental sustainability.

As per Indian Ministry of New and Renewable Energy (MNRE), on average, India generates half a billion metric tons (Mt) of crop residue every year. Although a significant fraction of this crop residue is used as fodder, fuel and for other domestic and industrial purposes, there still is an unutilized surplus of 140 Mt each year and 92 Mt of that are incinerated (NPMCR 2019). More agricultural wastes are generated in India than Bangladesh, Indonesia, and Myanmar combined. In fact, the agricultural waste volume that is incinerated in India is more than the net volume of agricultural waste produced by other countries in the region (Bhuvaneshwari et al. 2019).

In this review, we aim at constructing a picture of the state of agricultural waste and its generation. Agricultural wastes, their different types, and their characteristics have also been discussed. Apart from that, the key challenges and most promising opportunities in developing smart, sustainable, and efficient agricultural waste conversion mechanisms and residue management strategies are described.

1.2 Sources of Agricultural Waste Generation

Waste produced from agriculture can be broadly divided into two groups based on their composition namely:

- Lignocellulosic waste
- Proteinaceous waste

1.2.1 Lignocellulosic Waste

Lignocellulosic biomass is about 50% of the world's total biomass. Its annual production is around 10–50 billion tons (Mood et al. 2013; Kumar et al. 2018). It is the main constituent of the cell walls in plants and contains cellulose (40–60%), hemicellulose (20–40%), and lignin (10–25%) (Dionisi et al. 2015). The plant residues produced in agricultural field also come under this and are known as agricultural residues.

They can be grouped into two categories: field residues and process residues. Agricultural wastes which remain in the field after the process of crop harvesting has been concluded are referred to as field residues. Field residues function as feedstock for a number of processes designed to transform agricultural waste into economically valuable products such as animal feed, organic manure, raw materials for different manufacturing industries, and even various biochemicals of clinical and industrial significance. However, these processes also produce by-products which are known as process residues. Field residues and process residues can include a variety of waste products like molasses, husks,

bagasse, seeds and seed pods, leaves, stems, straws, stalks, shells, and pulp. India being an agrarian nation produces nearly 686 million tons of lignocellulosic waste and 234 million tons of that are agricultural residues (Kapoor et al. 2020). But because of the current inefficiencies in plaguing agricultural waste management processes, a significant portion of the agricultural residues produced in India is underutilized. This also presents an opportunity for future initiatives aimed at processing agricultural waste and turning waste into wealth.

1.2.2 Proteinaceous Waste

Proteins are known part of our daily nutrition and biochemical function. They also are promising sources of raw material for polymers. The protein obtained from agricultural waste has a huge potential for various utilities. The waste produced from aquaculture and livestock are abundant in protein and can be utilized to derive novel ways to produce value-added products (Barone Justin and Schmidt Walter 2006). So, the proteinaceous waste can be from two major sources: (i) aquaculture and (ii) livestock.

1.2.2.1 Waste Produced from Aquaculture

The expansion of aquaculture has resulted in an increased feeding of feed for improved aquaculture productivity. In a proper aquaculture installation, approximately 30% of the feed fed is converted into solid waste. In aquaculture, the most prominent wastes generated are the metabolic wastes. It could be in soluble or suspended form. Since feeding rates are ambient temperature-dependent, rise in temperature leads to increased feeding. This consequently results in increase in volume of waste being generated. Optimized patterns of water flow in the production units are critical considerations for waste management as proper water flow minimizes fish faecal matter fragmentation and enables the rapid sedimentation of insoluble solid waste. Furthermore, if the non-fragmented waste like faeces is higher in amount, it becomes easier to capture them, and this greatly reduces the concentration of dissolved organic waste in the system (Mathieu and Timmons 1995; Obi et al. 2016).

1.2.2.2 Waste Produced from Livestock

Waste generated by livestock activities is produced from different sources. Slaughterhouses produce organic materials and solid wastes like manure, whereas animal's farms produce high amount of animal faeces and fodder waste. Urine, water produced during cage washing, water from bathing animals, and water from cleaning of slaughterhouses are part of the wastewater produced from livestock activities. Also, air pollutants like H_2S and CH_4 and odour are produced here. These wastes if not managed well contribute to greenhouse gas production and affect the soil and water quality. These also act as a source of bad odour and site for parasites and germs making them a threat for human health and environment (Obi et al. 2016). Poultry industry is also expanding with increase in consumption of poultry products. The feather left out from the birds are contributing significantly to the waste. This waste is mainly composed of protein (90%), specifically keratin which is insoluble and is hard to degrade naturally. Hence, better management is needed to utilize these wastes (Jana et al. 2020).

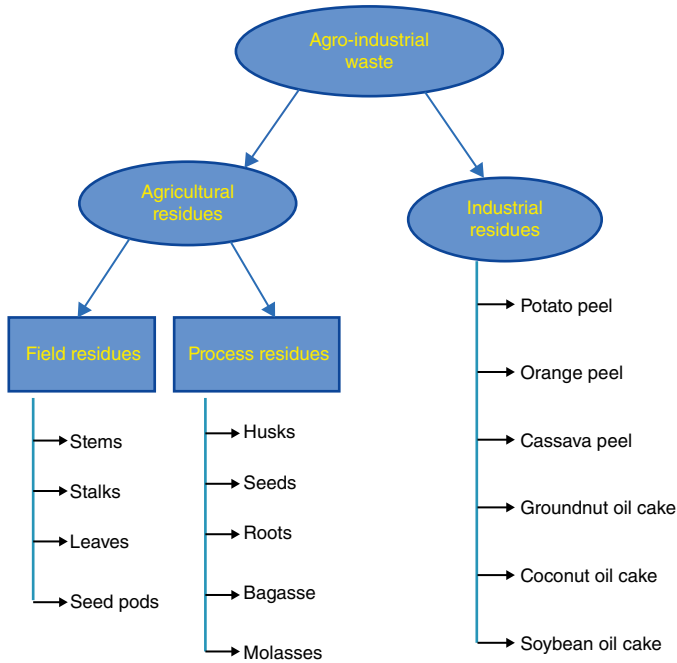


Figure 1.1 Agro-industrial waste materials. *Source:* Sadh et al., 2018 / Public Domain / CC BY 4.0.

Figure 1.1 shows the different types of Agro-industrial waste of their potential sources.

Table 1.1 Chemical composition of residues.

Name	Carbon (%)	Nitrogen (%)	Hydrogen (%)
Wheat bran	49.81	0.7	6.11
Rice bran	48.39	0.89	5.43
Oat bran	40.62	0.31	4.31
Corn cob	53.61	1.91	8.97
Sugar cane bagasse	48.32	0.2	7.84
Redgram husk	42.23	ND	5.52
Green gram husk	43.17	1.86	ND
Bengal gram husk	42.45	0.75	5.82
Black gram husk	39.61	2.34	5.87
Ground nut oil cake	40.34	2.31	4.21
Spent coffee	34.51	0.36	3.95
Spent tea	32.61	0.31	ND
Pineapple waste	45.68	0.61	3.97
Palmoil fiber	41.4	1.67	5.44
Coconut oil cake	48.16	1.69	5.15

ND not detectable.

Source: Thadikamala and Reddy Shetty (2013) / Springer Nature.

1.3 Agricultural Waste Characterization

Knowing the characteristics of agricultural waste is important for formulating an effective waste management system. Wastes produced from agriculture vary in both their quality and quantity. Wastes produced by the processing of crops and from livestock need both solid and liquid waste management. Knowing the characteristics of waste helps in reusing the waste, recovery of useful components, production of useful products like biofuels, biofertilizers, and overall management (Loehr 2012). Table 1.1 shows the chemical composition of waste having different resources. The wastes can be categorized on the basis of their sources as given in the following sections:

1.3.1 Food Processing

The variation in wastes produced during food processing is due to the type of product, methods used to harvest the raw materials, and the processing methods used. For example, wastes generated from fruit and vegetables are often acidic and contain good amount of organic matter. Also, wastes from fruit and vegetable processing from operations like peeling and blanching have high percentage of total dissolved organic solids. The analysis of edible part of vegetables has shown the presence of water (74–94% of total weight), carbohydrate (3.2–19.1% of total weight), protein (1.1–6.7% of total weight), and fat (0.1–0.5%). Also processes like washing contribute to production of wastewater (Loehr 2012). Apart from this, crop residues left after harvest are also the major waste produced and are of high concern, especially in countries like India. They comprise cellulose, hemicellulose, lignin, nitrogenous material, chlorophyll, and other inorganic material (Bhuvaneshwari et al. 2019). Food wastes also consist of natural as well as anthropogenic toxins such as solanine and dioxin which needs to be excluded to make the quality control systems more efficient. Also, the less use of potentially hazardous products in food processing will lead to the generation of less toxic waste making its management easy (Pandey and Dwivedi 2020).

1.3.2 Meat and Poultry Processing Industry

The main waste produced in this is from killing, dehairing, removal of hide, processing, and other clean-up operations. It contains blood, inorganic and organic solids, salts, and chemical used during processing. Usually at a beef slaughterhouse, 50-lb blood, 50-lb paunch manure, and 40-lb animal manure per animal can be produced. At poultry processing farms, waste is generated by killing, scalding, defeathering, evisceration, washing, chilling, and clean-up activities. Quantity and quality of waste generated totally depend on how processes are being handled. With the expansion of poultry industry, water usage, biological oxygen demand (BOD), and solid waste produced have also increased. Now, water used for each bird is about 12–15 gal, BOD produced is 60 lb/1000 birds, and solid waste produced is about 47 lb/1000 birds. These industries are not much affected by seasonal variations, and with expansion of these industries, the waste produced is also of high concern (Loehr 2012).

1.3.3 Livestock Waste

The characteristics of animal waste may be defined on the basis of changes in environment and overall productivity of the animals. The volatile matter present in the waste is found by summing up the percent of protein, fat, fibre, and non-fibre found in feed after digestion.

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