



RESEARCH ARTICLE

Optimizing Carica Waste Processing into Liquid Organic Fertilizer Using Bioconversion Techniques to Increase Agricultural Productivity in Kejajar District, Wonosobo

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Abstract

This community service program aims to optimize the use of Carica (*Carica pubescens*) waste into liquid organic fertilizer through bioconversion techniques, while simultaneously increasing the capacity of MSMEs and farmer groups in Kejajar District, Wonosobo. Activities include outreach, training, and mentoring in the production of liquid organic fertilizer on a household scale using simple technology based on decomposer microbes. The results of the community service show an increase in partners' knowledge and skills in Carica waste fermentation techniques, as well as in the production of liquid organic fertilizer with physical, chemical, and microbiological properties suitable for organic farming. Analysis shows decrease in pH and color changes, a distinctive fermentation odor, and increases in nutrient content (N, P, K), along with variations in substrate concentration. In addition, participants received mentoring on digital marketing strategies to increase the product's economic value. This program contributes to reducing Carica industrial waste, providing alternative organic fertilizers, and empowering local communities to improve welfare based on regional potential.

Keywords: Carica, bioconversion, liquid organic fertilizer, MSMEs, community empowerment

Introduction

Kejajar District, located in Wonosobo Regency, Central Java, has significant agricultural potential, particularly in the cultivation of Carica, or mountain papaya. Carica is a plant native to the Dieng Plateau and thrives only in cool temperatures, fertile volcanic soil, and high rainfall. These advantages make Carica one of the leading commodities in the Kejajar area. Despite its high economic value and being a sought-after specialty product for tourists, Carica utilization in Kejajar District is still limited to the sale of fresh fruit [1]. The Carica processing industry, such as the production of Carica preserves, syrup, jam, and fermented products, has not yet fully developed. Local farmers and businesses still face various obstacles, such as lack of access to modern processing technology, limited skills in post-harvest processing, and challenges in marketing and distribution of processed products [2].

Carica plantations in Kejajar are a vital part of the region's agricultural sector. Farmers in this area generally cultivate Carica on farmland scattered throughout the villages, using monoculture or intercropping methods, primarily with crops such as potatoes, cabbage, and carrots. Most farmers still manage their farmland traditionally, although some have begun to implement modern farming techniques to increase yields [3]. The Carica harvest in Kejajar is generally used for various purposes, from household consumption to raw materials for the food industry and typical Dieng souvenirs [4].

To increase the added value of Carica harvests, the development of a technology-based processing industry is needed, as well as training for farmers and MSMEs in processing Carica into more varied and high-value products. Furthermore, a broader marketing strategy, whether

through local markets, e-commerce, or collaboration with the tourism sector, can help increase the competitiveness of Carica products from Kejajar [5]. With innovation in processing and marketing, the potential of Carica in Kejajar District can continue to grow and provide a greater economic impact for the local community [6].

Processing waste into organic fertilizer is an innovative solution to address environmental issues while simultaneously increasing the added value of food industry waste. In Kejajar District, Wonosobo Regency, one of the leading commodities widely cultivated and processed is Carica (*Carica pubescens*), or mountain papaya. Carica processing industries, such as the production of candied fruit and syrup, generate large amounts of organic waste, primarily in the form of peels, seeds, and pulp [7]. This waste is often simply thrown away and has the potential to pollute the environment if not managed properly. However, Carica waste contains nutrients that can be used as raw material for liquid organic fertilizer, which can be used to improve soil fertility and agricultural productivity [8].

The process of processing Carica waste into liquid organic fertilizer can be done through the bioconversion method, namely by microbial fermentation using bacteria such as *Lactobacillus sp.* and *Bacillus sp.* which are able to decompose organic compounds in waste into fertilizer rich in macro and micro nutrients, such as nitrogen (N), phosphorus (P), and potassium (K) [9]. The stages of this process include collecting Carica waste, chopping and mixing it with a decomposer microbe solution and additional ingredients such as molasses or brown sugar to speed up fermentation, incubation for 10–14 days, and filtering to produce liquid fertilizer that is ready to use [10]. With this method, previously unused waste can be converted into products that are useful for the agricultural sector, especially for farmers in Kejajar District.

Apart from having an impact on reducing waste and environmental pollution, processing Carica waste into liquid organic fertilizer also has economic potential [11]. Farmers and small business owners can use this fertilizer for their own agricultural needs or sell it as an organic fertilizer product which is increasingly in demand as the trend towards environmentally friendly farming grows [12]. To increase the success of this program, training and mentoring are needed for the community to understand efficient fertilizer production techniques and appropriate marketing strategies. With sustainable Carica waste processing, it is hoped that a circular agricultural system will be created, where waste is converted into useful resources, reducing dependence on chemical fertilizers and improving the welfare of farmers and the community in Kejajar District, Wonosobo [13].

Materials and methods

Materials

The main material used in this study was carica waste, consisting of skin, seeds, and pulp from the candied fruit and syrup processing industry. This waste was chosen because it is abundantly available, easily obtained, and contains various organic compounds that have the potential to be further utilized through the fermentation process. As an additional material, EM4 (Effective Microorganisms) or microbial inoculum containing *Lactobacillus sp.*, *Bacillus sp.*, and other decomposer microbes was used to support the biodegradation process. Glucose was added as a carbon source to accelerate microbial fermentation activity and serve as an alternative to molasses. Clean water was used as a fermentation medium to create conditions that support the growth of microorganisms. In addition, rice bran or brown sugar can be added optionally as additional nutrient sources to increase the effectiveness of the fermentation process.

Method

Socialization and Partner Education

The program was initiated with a socialization and educational session for the partner SMEs regarding the potential utilization of Carica waste as raw material for liquid organic fertilizer (LOF) production. The materials presented included the organic content of the waste, the benefits of LOF for soil fertility improvement, the basic principles of bioconversion through fermentation, and sustainable waste management strategies based on circular economy concepts. This activity

aimed to enhance the partners' understanding and readiness to implement the introduced technology.

Raw Material Collection and Preparation

Carica waste consisting of peels, seeds, and pulp residues was collected from the partner SMEs. The waste was chopped using a simple cutting tool into smaller pieces to increase the surface area and accelerate the decomposition process during fermentation. The prepared material was then weighed according to substrate concentration variations of 20%, 30%, and 40% (w/v), which were applied as experimental treatments.

Bioconversion Fermentation Process

The prepared Carica waste was placed into closed fermentation containers (plastic jerrycans or buckets). EM4 was added at 10% (v/v) as a microbial inoculum, along with 5% (w/v) glucose as an additional carbon source, followed by the addition of clean water to reach the designated final volume. The fermentation containers were tightly sealed and equipped with a small vent or gas outlet hose to release gases produced during fermentation, thereby maintaining semi-anaerobic conditions. Fermentation was carried out for 7-14 days at ambient temperature (20-24 °C), with manual stirring every 12-24 hours to maintain homogeneity and enhance organic matter biodegradation.

Quality Analysis of Liquid Organic Fertilizer

The resulting liquid organic fertilizer was evaluated through physical, chemical, and microbiological analyses. Physical analysis included pH measurement, as well as observation of color, odor, and turbidity. Chemical analysis was conducted to determine nitrogen (N), phosphorus (P), potassium (K), and organic carbon (C-organic) contents. Microbiological analysis involved Total Plate Count (TPC) enumeration and quantification of *Lactobacillus sp.* and *Bacillus sp.* populations to assess microbial dynamics and activity during the fermentation process.

Results and Discussion

Training and Technology Transfer

The technology transfer component of this community engagement program was implemented through a one-day intensive training session conducted for residents of Kejajar District, particularly small-scale entrepreneurs and farmer groups involved in Carica processing. The training focused on converting Carica waste into liquid organic fertilizer (LOF) using a household-scale bioconversion method that does not require heavy equipment or specialized fermentation drums. Participants were introduced to a simple fermentation process utilizing plastic buckets or recycled jerrycans with lids as fermentation vessels. Locally available microorganisms, such as EM4 and *Lactobacillus sp.*, were applied as inocula and mixed with Carica waste, molasses, and water. Waste size reduction was performed manually using kitchen knives or simple cutting tools, ensuring that the method remained highly accessible and feasible without significant financial investment.

The training was conducted through direct hands-on practice at the partner's location, covering raw material preparation, formulation and mixing of fermentation substrates, and proper storage techniques for the produced liquid fertilizer. Although the activity was completed within a single day, participants were provided with a simple illustrated module outlining the production steps systematically, enabling independent application at the household level. In addition, the session included a brief discussion on the agronomic benefits of organic fertilizer and the economic potential of marketing the final product. Through this concise yet intensive program, community members gained a clear understanding of basic bioconversion principles and initiated small-scale LOF production, demonstrating the effective achievement of practical and appropriate technology transfer objectives.

Physical Analysis of Fermented Liquid Organic Fertilizer

Table 1 presents the changes in the physical parameters of liquid organic fertilizer produced from Carica waste fermentation over 96 hours (4 days), with observations conducted every 12 hours. The observed parameters included pH, color, odor, and turbidity. At the beginning of fermentation (0 h), the pH of the solution was 6.8, with a light brown color, almost no detectable odor, and low turbidity (15 NTU). These initial conditions indicate that microbial activity had not yet become significant.

During the first 12–36 hours, a gradual decrease in pH was observed, reaching 6.0. The color became darker, and a slightly acidic odor began to develop. Turbidity increased significantly from 35 NTU to 85 NTU, indicating the onset of active microbial degradation of organic matter, leading to the formation of soluble compounds and suspended particles.

Between 48 and 72 hours, fermentation intensified, as reflected by a further decrease in pH to 5.5, a dark brown to nearly black coloration, and a stronger characteristic acidic fermentation odor. Turbidity exceeded 130 NTU, suggesting a high concentration of suspended solids due to increased microbial biomass and the accumulation of decomposition products. At this stage, the fermentation process approached a stable phase. From 84 to 96 hours, the pH slightly decreased to 5.3, while other physical parameters showed relatively stable conditions. The characteristic fermented odor remained consistent, and turbidity stabilized within the range of 140–145 NTU. The stabilization of turbidity values indicates that microbial activity had reached a stationary phase, suggesting that the liquid fertilizer was mature and ready for use or filtration prior to packaging.

Table 1. Changes in the Physical Parameters of Liquid Organic Fertilizer

Fermentation Time (h)	pH	Color	Odor	Turbidity (NTU)
0	6.8	Light brown	Almost odorless	15
12	6.5	Light brown	Slightly acidic	35
24	6.2	Moderately dark brown	Mild acidic	60
36	6.0	Dark brown	Acidic and slightly pungent	85
48	5.8	Deep dark brown	Strong acidic	110
60	5.6	Dark brown to blackish	Typical fermentation acidic odor	130
72	5.5	Dark brown to blackish	Stable acidic, non-putrid	135
84	5.4	Dark brown to blackish	Stable fermentation odor	140
96	5.3	Dark brown to blackish	Characteristic organic fertilizer odor	145

Overall, the data presented in Table 1 indicate that the fermentation process of liquid organic fertilizer derived from Carica waste proceeded optimally within a 4-day period, exhibiting consistent and progressive changes in physical parameters. The decrease in pH from 6.8 to 5.3 during fermentation reflects effective microbial activity, particularly by fermentative microorganisms such as *Lactobacillus sp.* and *Bacillus sp.*, in degrading complex organic compounds into simpler substances [14]. The increasing acidity observed throughout the process suggests the production of organic acids as metabolic by-products, which play an important role in improving soil structure and enhancing nutrient availability when applied to agricultural land [15]. In addition, the increase in turbidity from 15 NTU to 145 NTU indicates the accumulation of suspended particles and dissolved organic compounds in the fermentation medium. This trend demonstrates active decomposition and microbial biomass formation, as well as the successful solubilization of macro- and micronutrients from Carica waste into liquid form. Although

turbidity increased significantly, this condition remains acceptable for liquid organic fertilizer, as it reflects a high content of bioactive substances beneficial for plant growth.

Chemical Analysis of Fermented Liquid Organic Fertilizer

Table 2 shows that variations in the percentage of Carica waste substrate significantly influenced the chemical characteristics of the liquid organic fertilizer produced after 96 hours of fermentation. The results indicate that higher substrate percentages corresponded to increased concentrations of essential nutrients, including nitrogen (N), phosphorus (P), potassium (K), and organic carbon (C-organic).

At a 20% substrate concentration, the solution exhibited a pH of 5.5, with nitrogen content of 0.32%, phosphorus 0.14%, potassium 0.21%, and organic carbon 4.3%. These values suggest that microbial activity was sufficiently active to degrade a substantial portion of organic compounds into plant-available nutrients. However, when the substrate concentration was increased to 30% and 40%, a significant enhancement in all chemical parameters was observed. For instance, at 40% substrate concentration, nitrogen content increased to 0.42%, phosphorus to 0.18%, potassium to 0.28%, and organic carbon to 5.0%. This trend indicates that a greater availability of organic matter during fermentation supported more intensive microbial growth and metabolic activity, resulting in a richer nutrient profile in the final product.

Table 2 Effect of Substrate Percentage on the Chemical Characteristics of Liquid Organic Fertilizer After 96 Hours of Fermentation

Substrate Percentage (w/v)	pH	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Organic Carbon (%)
20%	5.5	0.32	0.14	0.21	4.3
30%	5.4	0.36	0.16	0.24	4.6
40%	5.3	0.42	0.18	0.28	5.0

The decrease in pH from 5.5 to 5.3 at higher substrate concentrations indicates that the fermentation process became more active, leading to the production of organic acids such as lactic acid and acetic acid. This increased acidity contributes to the stability of the liquid organic fertilizer and facilitates nutrient release in the soil upon application. The rise in organic carbon content in line with increasing substrate percentage suggests that a greater amount of carbon compounds was solubilized into forms available for plant utilization. Organic carbon plays a crucial role in improving soil structure, enhancing cation exchange capacity (CEC), and supporting the growth of beneficial soil microorganisms [16]. Overall, these results demonstrate that a 96-hour fermentation period with substrate concentrations of 30–40% represents an optimal condition for producing liquid organic fertilizer with favorable chemical quality. However, the selection of the ideal substrate concentration should still consider user requirements, raw material availability, and production efficiency. This approach highlights the significant potential of Carica waste as a valuable raw material for high-performance liquid fertilizer in supporting sustainable organic agriculture.

Microbiological Analysis of Liquid Organic Fertilizer Derived from Carica Waste

Table 3 presents the development of microbial populations in liquid organic fertilizer produced from Carica waste fermentation at a substrate concentration of 40% over a 96-hour period. The microbiological parameters analyzed included Total Plate Count (TPC) as an indicator of the total viable microbial population, as well as two key functional microorganisms, *Lactobacillus sp.* and *Bacillus sp.*, which play active roles in the bioconversion process. At the beginning of fermentation (0 h), the microbial population was relatively low, with a TPC value of 1.0×10^5 CFU/mL. This represents the natural microbial load present in the substrate prior to inoculation and fermentation activation. After 24 hours, a significant increase in TPC was observed, reaching 8.5×10^6 CFU/mL, corresponding to the initiation of microbial activity

following the addition of a fermentation starter such as EM4. This increase indicates that the fermentation medium had become conducive to microbial growth, which was further supported by the rise in *Lactobacillus sp.* population to 4.0×10^6 CFU/mL and *Bacillus sp.* to 3.0×10^6 CFU/mL.

Table 3 Microbial Population Dynamics During 96 Hours of Fermentation of Liquid Organic Fertilizer (40% Substrate Concentration)

Fermentation Time (h)	Total Plate Count (CFU/mL)	<i>Lactobacillus sp.</i> (CFU/mL)	<i>Bacillus sp.</i> (CFU/mL)
0	1.0×10^5	5.0×10^4	4.0×10^4
24	8.5×10^6	4.0×10^6	3.0×10^6
48	2.2×10^7	1.2×10^7	9.0×10^6
72	2.8×10^7	1.5×10^7	1.1×10^7
96	2.5×10^7	1.3×10^7	1.0×10^7

The microbial population continued to increase and reached its peak at 72 hours of fermentation. At this point, the Total Plate Count (TPC) reached 2.8×10^7 CFU/mL, with *Lactobacillus sp.* at 1.5×10^7 CFU/mL and *Bacillus sp.* at 1.1×10^7 CFU/mL. This stage represents the exponential growth phase, during which nutrient availability remained sufficient and microbial metabolic activity was at its optimum level [16]. These microorganisms function synergistically: *Lactobacillus sp.* produces organic acids that contribute to pH reduction, while *Bacillus sp.* facilitates the decomposition of complex organic materials such as lignocellulose into more soluble components [17].

Toward the end of fermentation (96 hours), a slight decline in total microbial count was observed, decreasing to 2.5×10^7 CFU/mL. This reduction is typical and reflects the stationary phase, where nutrient depletion and the accumulation of inhibitory metabolites, such as organic acids, begin to limit microbial growth [18]. Nevertheless, the microbial population remained at a relatively high and active level, sufficient to maintain the biological quality of the resulting liquid organic fertilizer [19]. These findings suggest that fermentation for 72–96 hours with a 40% substrate concentration represents an optimal condition for achieving the highest population of functional microorganisms, which directly enhances the effectiveness of organic matter bioconversion into high-quality liquid fertilizer. A high microbial population is also advantageous because these beneficial microorganisms continue to function in the soil after fertilizer application, accelerating the decomposition of plant residues and naturally improving soil fertility [20].

Conclusion

The community engagement program conducted in Kejajar District, Wonosobo Regency, successfully enhanced the capacity of local communities and SMEs to utilize Carica waste as raw material for liquid organic fertilizer production through a bioconversion process with the addition of glucose as a carbon source. The applied fermentation process effectively produced high-quality liquid organic fertilizer, as indicated by a decrease in pH, changes in color, the formation of a characteristic fermentation aroma, and an increase in macro-nutrient content (N, P, and K) as well as organic carbon, which reached optimal levels at a 40% substrate concentration. The activity of functional microorganisms, particularly *Lactobacillus sp.* and *Bacillus sp.*, increased significantly during fermentation and played a crucial role in the decomposition of organic materials, thereby ensuring the biological quality of the resulting fertilizer. Beyond its technical achievements, the program also generated positive socio-economic impacts. Community members gained new skills in waste processing, access to appropriate and affordable technology, and digital marketing capabilities to expand product distribution networks. Overall, this program not only contributed to reducing Carica waste and minimizing environmental pollution but also provided an

environmentally friendly fertilizer alternative to support agricultural productivity while creating new business opportunities that contribute to the welfare of the local community.

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