

DEVELOPMENT OF CONVENTIONAL BIOTECHNOLOGY STUDENT WORKSHEETS THROUGH A STUDY OF LIQUID ORGANIC FERTILIZER UTILIZATION IN CELERY USING A HYDROPONIC SYSTEM

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ABSTRACT

Liquid waste from tofu production and rice washing that is directly discharged without prior treatment causes water pollution that negatively impacts the surrounding environment. Tofu wastewater and rice washing water contain relatively high levels of nitrogen (N), phosphorus (P), and potassium (K), making them suitable for use as raw materials in the production of liquid organic fertilizer (LOF) for celery plants. This study aimed to develop a design of Student Worksheets (LKPD) for the subtopic of Conventional Biotechnology Products for Grade X senior high school through a study on the utilization of LOF in celery using a hydroponic system. This research employed a mixed methods approach with a sequential mixed methods strategy. In the first stage, quantitative research was conducted using an experimental method. The results of the first stage served as the basis for the second stage, which involved a qualitative approach in the form of designing the LKPD for the subtopic of conventional biotechnology products. The experiment used a Completely Randomized Design (CRD) consisting of five treatments with three replications. The observed parameters included plant height, number of leaves, root length, fresh weight, and dry weight. The results showed that the combination of LOF from tofu wastewater and rice washing water had a significant effect on the growth of celery plants, with the combination treatment of 2.5 liters of tofu wastewater and 2.5 liters of rice washing water identified as the best treatment across all parameters, namely plant height, number of leaves, root length, fresh weight, and dry weight. The research findings were then integrated into the LKPD design and validated by experts as an LKPD that is appropriate for use in teaching conventional biotechnology for Grade X senior high school.

Keywords: Celery; Conventional Biotechnology; Student Worksheets; Liquid Organic Fertilizer; Hydroponics.

INTRODUCTION

The development of science, technology, and communication in the 21st century has provided great potential for improving the quality of education. Advances in various fields have driven changes in the education sector, particularly in the implementation of curricula as the main focus of the learning process. One such reform is the implementation of the *Merdeka Curriculum* by the Ministry of Education, Culture, Research, and Technology, which emphasizes the concept of independent learning as an effort to improve learning quality (Susanti et al., 2024).

The implementation of the *Merdeka Curriculum* provides flexibility in developing more adaptive teaching materials that emphasize project-based learning activities. This approach focuses on student involvement in producing products through a series of experimental and observational activities over a certain period of time (Destya, 2025). Teachers can design Student Worksheets (LKPD) that guide students to actively participate in each stage of the project, thereby enabling optimal development of students' science process skills.

One of the issues that can be used as a topic in LKPD development is the utilization of tofu wastewater and rice washing water as liquid organic fertilizer. Tofu wastewater and rice washing water, which are usually discharged directly into the environment, contain high levels of nutrients that are beneficial for supporting plant growth and development. Tofu wastewater contains N 1.24%, P 5.54%, K 1.34%, Ca 0.021%, and Mg 0.024%, while rice washing water contains N 1.22%, P 1.630%, K 0.02%, Ca 2.944%, and Mg 14.252% (Wibowo, 2020). This combination of liquid organic fertilizer can be used as an alternative fertilizer for vegetable crops, including celery.

The development of LKPD with the topic of producing liquid organic fertilizer made from tofu wastewater and rice washing water can help students directly understand conventional biotechnology through fermentation activities and the utilization of local materials. This activity aligns with Learning Outcome TP 10.3.4 in the *Merdeka Curriculum*, which states that students are able to produce organic fertilizer based on conventional biotechnology through experiments on making combinations of liquid organic fertilizer from tofu wastewater and rice washing water, and TP 10.3.5, which states that students are able to present the results of practical work on producing combinations of liquid organic fertilizer from tofu wastewater and rice washing water in the form of a report. Thus, students not only understand biological concepts theoretically but also relate them to real practices and phenomena in their surroundings.

The results of observations at SMA Negeri 1 Kerinci Kanan indicate that learning on the subtopic of conventional biotechnology products is limited to textbooks and material delivery through PowerPoint presentations. This limitation of media results in students not obtaining contextual learning experiences, especially for material that requires practical activities. The production of liquid organic fertilizer from tofu wastewater and rice washing water requires clear instructions and procedural steps to avoid procedural errors. Through these activities, it is expected that students' understanding of the material being taught can be improved. The development of this LKPD is expected to increase student participation, strengthen science process skills, and provide more meaningful and contextual learning experiences in the surrounding environment. Therefore, the purpose of developing an LKPD based on experiments on producing liquid organic fertilizer from tofu wastewater and rice washing water applied to celery using hydroponic techniques is to determine the validity of the LKPD as a biology teaching material for senior high school on the subtopic of Conventional Biotechnology Products, as well as to improve students' understanding through practice-based learning activities.

RESEARCH METHODS

This research was conducted at the Biology Education Garden of Universitas Riau and continued with the development of teaching materials at the Campus of the Biology Education Study Program, Faculty of Teacher Training and Education, Universitas Riau.

This study employed a mixed methods approach with a sequential mixed methods strategy. In the first stage, quantitative research was conducted using an experimental method to determine the effect of liquid organic fertilizer combinations on celery growth using a wick hydroponic system. The results from the first stage were then used as the basis for the second stage, which involved a qualitative approach in the form of designing LKPD for the subtopic of conventional biotechnology products. The development of the LKPD as a senior high school biology teaching material was carried out through three stages: Analyze, Design, and Development.

Data obtained from observations of plant height, number of leaves, root length, fresh weight, and dry weight were analyzed using Analysis of Variance (ANOVA). When the analysis results showed a significant difference with a significance value of < 0.05 , a follow-up Duncan Multiple Range Test (DMRT) at the 5% level was conducted to determine differences in treatment effects. The research data were analyzed using statistical analysis techniques with the assistance of SPSS 27 software.

The research procedure in the first stage began with experimental design using a Completely Randomized Design (CRD) consisting of five treatments with three replications, resulting in 15 experimental units. The treatments were P0 (control/no liquid organic fertilizer), P1 (2.5 liters of tofu wastewater + 1 liter of rice washing water), P2 (2.5 liters of tofu wastewater + 1.5 liters of rice washing water), P3 (2.5 liters of tofu wastewater + 2 liters of rice washing water), and P4 (2.5 liters of tofu wastewater + 2.5 liters of rice washing water). The parameters measured in this study were plant height, number of leaves, root length, fresh weight, and dry weight.

The experimental results of applying liquid organic fertilizer from tofu wastewater and rice washing water to celery growth using a wick hydroponic system were then used for LKPD development, starting from curriculum analysis, identification of learning outcomes, and identification of learning objectives. The next stage was the design of the LKPD, which included designing the Learning Objectives Flow (ATP), teaching modules, assessment instruments, and LKPD. This was followed by the development stage, in which the LKPD was developed according to the design stage, resulting in a draft LKPD. The developed product was then validated by two expert validators—one subject matter expert and one media expert—to determine the feasibility level of the LKPD and to obtain suggestions and feedback for improving the resulting LKPD product.

RESULTS AND DISCUSSION

Results of Analysis on the Effect of the Combination of Tofu Wastewater and Rice Washing Water on the Growth of Celery (*Apium graveolens* L.) Using a Wick Hydroponic System Based on Plant Height (Canopy Height), Number of Leaves, Root Length, Fresh Weight, and Dry Weight Celery Plant Height

Based on the results of the analysis of variance (ANOVA), it is known that the application of a combination of liquid organic fertilizer derived from tofu wastewater and rice washing water using a wick hydroponic system had a significant effect on celery plant height. After conducting the Duncan Multiple Range Test (DMRT) at the 5% level to examine differences among treatments, the results are presented in Table 1 as follows.

Table 1. Mean plant height of celery under various treatments of liquid organic fertilizer (LOF) dosages derived from tofu wastewater and rice washing water at 60 days after planting (DAP)

Treatment Concentration (L tofu wastewater + L rice washing water)	Celery Plant Height (cm)	Number of Celery Leaves (leaves)	Celery Root Length (cm)	Celery Fresh Weight (g)	Celery Leaf Weight (g)
P0 (0 + 0)	28,23 a	56,67 a	12,50 a	30,33 a	4,67 a
P1 (2,5 + 1)	31,03 ab	58,00 ab	12,70 a	33,67 ab	5,00 a
P2 (2,5 + 1,5)	31,76 b	60,33 ab	14,16 a	34,00 ab	6,67 ab
P3 (2,5 + 2)	34,00 b	62,00 bc	18,46 b	37,67 bc	8,33 b
P4 (2,5 + 2,5)	39,30 c	66,00 c	21,36 b	41,00 c	12,00 c

Note: Values followed by the same letter are not significantly different at the 5% significance level

The plant height results in Table 1 show that treatment P0 (control) produced a mean height of 28.23 cm. This was due to the lack of nutrients in the hydroponic medium and the absence of additional nutrient input for the celery plants, which inhibited metabolic processes and vegetative growth, thereby resulting in lower plant height. Celery plants that were not given liquid organic fertilizer appeared smaller, with stunted height growth. This occurred because the nutrients obtained were only derived from water, whose nutrient content was unknown. Consequently, metabolic processes in the celery plants proceeded slowly. Supriyanto et al. (2025) stated that low results in a treatment indicate that nitrogen (N), which plays an important role in increasing plant height, was insufficient to meet the nutritional requirements of celery plants, causing cell division, cell enlargement, and metabolic processes to not proceed optimally.

In treatment P4, the mean plant height reached 39.30 cm, with a higher availability of nutrients required by plants to support optimal growth and development. According to Mahadi et al. (2023),

the high nitrogen content in fermented liquid organic fertilizer can support chlorophyll formation in leaves. An increase in chlorophyll content enhances the absorption of sunlight, resulting in the production of photosynthates that serve as an energy source for cell growth and development. This process stimulates growth responses, including increased plant height.

Vegetable crops, including celery (*Apium graveolens* L.), require relatively high amounts of nitrogen, phosphorus, and potassium; therefore, these three nutrients must be available in sufficient and balanced quantities according to plant requirements. If these nutrients are unavailable, imbalanced, or supplied too late, plant growth and development will be inhibited (Sarwono, 1995, as cited in Firmansyah & Syakir, 2017).

Number of Celery Leaves

The results for the number of leaves in Table 1 show that treatment P0 (control) produced the lowest value, with an average of 56.67 leaves. This was due to the insufficient nutrient content in the growing medium to meet the nutritional requirements of celery plants and the absence of additional nutrient application. These conditions inhibited metabolic processes and vegetative growth, resulting in a lower number of leaves. This finding is consistent with the statement by Ikhsan et al. (2017), who reported that nitrogen deficiency in plants inhibits leaf formation.

Treatment P4 resulted in the highest average number of leaves, reaching 66.00 leaves. This indicates that the nutrients supplied in treatment P4 were sufficient to meet the nutritional requirements of celery plants, allowing more optimal leaf development. The number of leaves is related to plant height; the taller the plant, the greater the number of leaves produced. According to Purba et al. (2022), leaf formation is closely associated with plant height, showing that as plant height increases, the number of leaves formed also increases.

Celery Root Length

Based on the data in Table 1 for celery root length, treatment P0 (control) produced the lowest mean root length, which was 12.50 cm. This was due to the relatively low nutrient content in the liquid organic fertilizer, which was insufficient to meet the nutrient requirements for celery growth, particularly root development. Supriyanto et al. (2025) stated that when the nutrient levels in the growing medium do not meet plant requirements, nutrient absorption becomes suboptimal, resulting in short roots with small volume.

The best treatment for the root length parameter was observed in treatment P4, with a mean value of 21.36 cm. According to Ritonga and Idris (2024), an increase in root length indicates a balance between the plant's metabolic needs and nutrient uptake processes. The longer the roots formed, the greater the surface area for water and nutrient absorption from the growing medium, thereby supporting root tissue development and the growth of other plant tissues.

Celery Fresh Weight

The fresh weight data of celery in Table 1 show that treatment P0 (control) resulted in the lowest mean fresh weight, at 30.33 g. This was due to the lack of nutrients in the growing medium. Although the medium contained sufficient water, it was unable to increase the fresh weight of celery plants. In line with this, Saputra (2021) stated that the composition of the growing medium and nutrient availability has a significant effect on plant fresh weight; media with higher nutrient content produce greater fresh weight compared to control media without nutrient supplementation. This indicates that nutrient deficiency in the growing medium can inhibit vegetative growth, including plant fresh weight.

Treatment P4 showed the highest fresh weight, reaching 41.00 g. In this treatment, the nutrients supplied to the celery plants were sufficient to meet their nutritional requirements. Jupry et al. (2020) stated that adequate availability of water and nutrients automatically accelerates increases in both fresh and dry weight of plants. Consistent with this, Okalia et al. (2021) reported that higher concentrations of liquid organic fertilizer contribute greater amounts of N, P, and K nutrients, resulting in better plant growth and increased biomass production.

Dry Weight

The data in Table 1 show that treatment P0 (control) produced the lowest dry weight. This was because, in treatment P0, the nutrients available in the growing medium relied solely on water without the addition of liquid organic fertilizer, resulting in insufficient nutrient availability to meet the nutritional requirements of celery plants. Consequently, celery plants had a high water content but low nutrient accumulation. This condition inhibited metabolic processes and vegetative growth, leading to low celery dry weight. Nutrient availability affects the rate of photosynthesis and

metabolism required for biomass formation. Insufficient nutrients result in lower dry biomass compared to plants that receive adequate nutrition (Haryadi et al., 2015).

Treatment P4 produced the highest dry weight because this treatment provided sufficient nutrient availability in accordance with the needs of celery plants, allowing optimal nutrient uptake to support metabolic and photosynthetic processes, which in turn increased dry biomass accumulation. This finding is consistent with Lussy et al. (2025), who stated that the more adequately nutrients are supplied to plants, the higher the dry weight production compared to treatments with lower nutrient availability.

Potential of the Research Findings as a Design for Senior High School LKPD Learning Analyze

This stage describes curriculum analysis and learning analysis. The curriculum analysis begins with a review of the curriculum, namely the *Merdeka Curriculum*. The next step is identifying relevant Learning Outcomes (CP) that have the potential to be developed based on the results of the research conducted and can be used as a basis for preparing the LKPD. In the initial stage, an analysis of the Learning Outcomes (CP) for Senior High School Biology Phase E was carried out, followed by an analysis of Learning Objectives (TP) to ensure that the learning outcomes at that phase can be achieved. The results of the material analysis are presented in Table 2 as follows.

Table 2. Analysis of Materials with Potential to Be Developed in the LKPD Design

Results of Material Analysis	Subtopic	Grade/Semester
Conventional Biotechnology: producing liquid organic fertilizer made from tofu wastewater and rice washing water	Conventional Biotechnology Products	X/Even Semester

The research data have the potential to be developed as enrichment material for the subtopic of conventional biotechnology products for Grade X in the even semester. This material enables the implementation of research-based learning through the stages of the scientific method, namely problem formulation, experiment implementation, conclusion drawing, and preparation of activity reports. This approach is in accordance with the learning model applied, namely Project-Based Learning (PjBL). Therefore, the material selected as the basis for developing the LKPD is Conventional Biotechnology in the second meeting, particularly the subtopic of conventional biotechnology products. The results of the analysis of Learning Outcomes (CP) are presented in Table 3 as follows.

Table 3. Learning Outcomes Related to the Research

Learning Outcomes	Subtopic	Meeting	Learning Objectives
Students are able to create solutions to problems based on local, national, or global issues related to the understanding of biodiversity and its roles, viruses and their roles, biological technology innovations, ecosystem components and interactions among components, and environmental changes	Conventional Biotechnology Products	2	Students are able to produce organic fertilizer based on conventional biotechnology through an experiment on making a combination of liquid organic fertilizer from tofu wastewater and rice washing water
		4	Students are able to present the results of practical work on producing a combination of liquid organic fertilizer from tofu wastewater and rice washing water in the form of a report

Data from the research results used in the development of the LKPD for the second meeting involve conducting an experiment on producing liquid organic fertilizer from tofu wastewater and rice washing water. Subsequently, in the fourth meeting, students present the experimental results in the form of a report.

Design

At this stage, the LKPD was designed in accordance with the *Merdeka Curriculum*. The design stage consisted of two phases, as follows.

a. Design of Learning Tools

This phase began with the preparation of the Learning Objectives Flow (ATP), teaching modules, and assessment instruments. The preparation of the ATP was aligned with the Learning Outcomes (CP) for Phase E and was designed for six meetings.

b. LKPD Design

The LKPD design stage began with the preparation of material concepts aligned with the facts and data obtained from the research results. The LKPD was developed using the Canva

application. The structure of the LKPD followed Ma'wa (2019), consisting of a cover, identity, Learning Objectives (TP), discourse, learning resources, learning instructions, tools and materials, work procedures, activity results, questions, and conclusions. The appearance of the LKPD cover design used in this study is shown in Figure 1.

Figure 1. LKPD Design



The following describes the implementation of the LKPD structure for the subtopic of conventional biotechnology products.

- 1) **Cover**, presented attractively with a combination of green, yellow, and cream colors. It includes information describing the content of the student worksheet, namely the LKPD title “Production of a Combination of Liquid Organic Fertilizer from Tofu Wastewater and Rice Washing Water.” Information regarding the material and grade level is also provided, indicating that the LKPD is used for the subtopic of conventional biotechnology products for Phase E Grade X senior high school/MA. Images of tofu wastewater and rice washing water are displayed. In addition, the name of the author along with the student identification number (NIM) and the names of the two supervisors are written on the center-left section of the cover.
- 2) **Identity**, which provides information about the LKPD, consisting of components such as school name, subject, main material, meeting, group, and group member names.
- 3) **Objectives**, which are the specific competencies that students need to master after participating in learning activities in order to achieve the Learning Outcomes (CP) of a particular phase. The learning objectives in this LKPD development are that students are able to produce a conventional biotechnology-based product through an experiment on making a combination of liquid organic fertilizer from tofu wastewater and rice washing water in the second meeting, and that students are able to present the results of the practical work on producing a combination of liquid organic fertilizer from tofu wastewater and rice washing water in the form of a report in the fourth meeting.
- 4) **Discourse**, which contains information related to the material integrated into the LKPD, namely the importance of utilizing tofu wastewater and rice washing water as liquid organic fertilizer (LOF).
- 5) **Learning resources**, which are sources of information used by students as references to complete the tasks in the LKPD, such as textbooks and research articles.
- 6) **Instructions**, which contain steps for students to follow in completing the LKPD. These instructions aim to facilitate students’ understanding of how to use the LKPD.
- 7) **Tools and materials**, which list the tools and materials that students must prepare when conducting the practicum on producing liquid organic fertilizer from tofu wastewater and rice washing water.
- 8) **Procedures**, which describe the process of producing liquid organic fertilizer derived from tofu wastewater and rice washing water.

- 9) **Activity results**, which are records of data or information obtained directly through observation and measurement activities carried out by students during the experiment or practicum.
- 10) **Questions**, which consist of items designed to encourage students to think critically and reflectively about the material being studied.
- 11) **Conclusion**, which summarizes the results of the learning activities that have been carried out. Students can reflect on what they have learned during the learning process.

Development

At this stage, validation of the developed product was conducted. Validation sheets were completed by two validators, namely a subject matter expert and a media expert. The results of the validation by the subject matter expert and the media expert are presented in the following table.

Table 4. Results of Validation by Subject Matter Experts and Media Experts

Aspect	Criteria	Validator		Σ Score	Average Score per Aspect	Validity
		I	II			
Content Feasibility	1	4	4	53	3,785	Very Valid
	2	4	4			
	3	4	4			
	4	3	4			
	5	4	4			
	6	3	4			
	7	4	3			
Language Feasibility	1	3	3	35	3,5	Very Valid
	2	3	4			
	3	3	4			
	4	3	4			
	5	4	4			
Display Feasibility	1	4	3	99	3,807	Very Valid
	2	4	4			
	3	4	4			
	4	4	3			
	5	4	4			
	6	3	4			
	7	4	4			
	8	4	4			
	9	4	4			
	10	3	4			
	11	3	4			
	12	4	4			
	13	4	4			
Jumlah		91	96	187	11,092	
Average		3,640	3,840		3,697	Very Valid

Based on Table 4, the validation results of the LKPD for content feasibility, language feasibility, and display feasibility were 3.640 from the subject matter expert and 3.840 from the media expert. The average validation score of the LKPD from both validators was 3.697, which falls into the “very valid” category. This indicates that the LKPD designed meets the criteria of suitable teaching materials for use in the learning process.

The improvements suggested by the subject matter and media experts to refine the LKPD were as follows:

- a) Replace the tofu wastewater image with one that is more focused on the cover section.
- b) Add the process of molasses preparation in the procedures section.
- c) Include additional explanations in the observation results.
- d) Enlarge the graph image in the questions section.

Based on the suggestions provided by the subject matter and media experts, the researcher made revisions to the LKPD to improve the developed product. The LKPD presented in this study is the revised version, adjusted according to the recommendations from both validators. Therefore, this LKPD is considered suitable for use in biotechnology learning, particularly for the subtopic of conventional biotechnology products.

CONCLUSION

Based on the results of the study, the application of a combination of liquid organic fertilizer from tofu wastewater and rice washing water had a significant effect on the growth of celery (*Apium graveolens* L.) using the wick hydroponic system. The best treatment was the combination of 2.5 liters of tofu wastewater and 2.5 liters of rice washing water, which produced optimal results for all parameters, including plant height, number of leaves, root length, fresh weight, and dry weight. These research results served as the basis for developing the LKPD for the Conventional Biotechnology subtopic for Grade X senior high school. The LKPD was designed to include content on the utilization of organic waste relevant to the students' local context. It was structured in a project-based format using the Project-Based Learning (PjBL) model, containing step-by-step work instructions, fermentation data of the liquid organic fertilizer, and several questions/tasks for students to complete. Validation results showed that the developed LKPD received a score of 3.697, categorized as "very valid," indicating that it is suitable for use as contextual teaching material to help enhance students' understanding of conventional biotechnology concepts.

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