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Production of tempe *koro benguk* using local starter and its implementation as a biotechnology module for high school students

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ABSTRACT

The *Kurikulum Merdeka* emphasizes integrating local wisdom into education to develop students' soft skills and character. Traditional foods like *koro benguk* tempe (TKB), a fermented product made from *Mucuna pruriens* (L.) DC. from Dimoro Village, Central Java, offer an excellent avenue for such integration in biotechnology education. A survey at Yadika 4 High School revealed a lack of local wisdom-based practical guides, demanding the need for resources that could enhance student engagement in biotechnology knowledge. This study developed practical guidelines for TKB production, focusing on its organoleptic properties, integration feasibility, and feedback from teachers and students. Laboratory experiments and module development were combined to collect data. Organoleptic tests identified 0.3% starter concentration as optimal, producing tempe with a white color, soft texture, and pleasant taste. The practical guidelines achieved a validation score of 89% from language, material, and media experts, while teachers rated them at 90%, and students responded positively with a 73% score. Further research is needed to refine the fermentation process of TKB beyond 36 hours and analyze its pH content. Expanding the study to include other fermented local products could further enhance biotechnology learning. Integrating local wisdom through practical guides not only promotes cultural preservation but also improves students' memory, manipulative skills, creativity, communication, and responsibility.

Keywords: Biotechnology module, fermentation, local wisdom, *Mucuna pruriens*, organoleptic

INTRODUCTION

Tempe, a traditional and highly popular food in Indonesia, is renowned for its nutritional value and health benefits (Bintari & Parman, 2019; Romulo & Surya, 2021). While tempe is typically made from soybeans, the increasing demand and price volatility of soybeans have prompted the search for alternative, cost-effective raw materials that retain high nutritional content. Tempe *koro benguk* (TKB) is a traditional food made from the local legume, *koro benguk* (*Mucuna pruriens* (L.) DC.), instead of soybeans. This delicacy is becoming increasingly rare as the number of households producing it in Dimoro Village has dwindled.

The decline in production is largely due to the lack of knowledge transfer from the older generation to the younger generation. Another significant factor contributing to the disappearance of TKB production is the lengthy and complex production process, which involves removing cyanide (HCN) content from the beans. HCN is released from cyanogenic compounds in certain nuts and seeds during water absorption and early germination, and may be reduced or eliminated during the fermentation process (Abdulhalim & Mohammad, 2023). Collectively, these situations pose a threat to the preservation of this local wisdom among future generations. Furthermore, the potential of *koro benguk* as a tempe ingredient remains underutilized due to limited information and public understanding of its fermentation process and the resulting product's quality.

In reality, this traditional practice supports Indonesia's biodiversity. Biodiversity, or the "diversity of living species", is a crucial topic for 10th-grade high school students to understand (Hevila *et al*., 2023). Incorporating the traditional practice of making TKB into the curriculum could enhance student's understanding of biodiversity and its importance. Traditional knowledge, often passed down through generations of indigenous communities, provides valuable insights and strategies for sustainable use and management of natural resources (Kossi *et al*., 2021).

Several studies related to *koro benguk* have been reported. For instance, Purwanti (2019) investigated the organoleptic properties of yogurt with the addition of *koro benguk*. Suwasono *et al*., (2022) discussed introducing *koro* beans as an alternative main ingredient for tempe production. Rahayu *et al*., (2019) examined the nutritional dynamics in terms of peptide concentration and protein patterns during the fermentation process of TKB using a commercial starter, Raprima™. However, there is a notable lack of scientific studies on the production of *koro benguk* using local starters, making this study particularly interesting. The local starter is made from dried TKB, ground into a fine powder. Furthermore, there have been no studies correlating this process with biotechnology education for high school students.

Biotechnology plays a crucial role in everyday life, particularly in the food sector, yet students' understanding is often limited to theoretical concepts without practical application. To bridge this gap, integrating research on *koro benguk* tempeh production into high school biotechnology modules can provide students with a meaningful learning experience by demonstrating how biotechnology principles are applied in everyday life, particularly in the tempeh fermentation process (Budiarti & Oka, 2017).

Tempe production, a form of basic biotechnology utilizing the fungus *Rhizopus* sp., especially *Rhizopus oligosphorus* (Jiang *et al*., 2017) serves as an ideal case study for this integration. By developing a practical guide based on local wisdom, students can better grasp scientific concepts while preserving cultural heritage, as local knowledge enhances the learning of biotechnology and fosters a deeper connection to the material. According to Adinugraha (2018), students can more easily construct scientific concepts through the integration of local wisdom in science teaching, which also serves as an effort to preserve the cultural heritage of various ethnic groups.

This study aligns with the main characteristics of the independent curriculum, which emphasizes the development of students' soft skills and character through project-based learning. One of the seven main themes in the independent curriculum is the integration of local wisdom into the learning process (Festiyed *et al*., 2022). This integration can be achieved by aligning local wisdom with specific learning objectives, reflecting the holistic orientation of the independent curriculum. This curriculum emphasizes competency-based, contextualized, and personalized learning tailored to the needs of students, the cultural context, the school's mission, and the local environment. Local wisdom is often embodied in traditional foods, making it an ideal subject for such an educational approach.

Improving human resource capacity can be achieved through school environments; however, the equal distribution and standardization of learning modules are still being developed to foster interest and effectively implement local content in an educational and impactful way (Larson & Murray, 2008). A preliminary survey at Yadika 4 High School in Bekasi, Indonesia, revealed a strong enthusiasm among teachers for local wisdom-based practical guides, yet no such resources are currently available, and access to module development remains limited.

Developing such a guide could enhance students' curiosity and interest in learning how to make TKB. According to Ernaliza (2018), a practical guide based on local wisdom can significantly boost students' interest in learning, particularly biology. Soplantila *et al*. (2023) also stated that teaching materials correlated with local wisdom serve as concrete examples that facilitate students' understanding of biology concepts.

To address this issue, a study was conducted to produce TKB using a local starter. The results of this study were used to create an educational output for a local wisdom-based biotechnology module, specifically the laboratory guidelines. The urgency of creating these guidelines is to facilitate the learning process and serve as an information resource for students. The module is a systematically structured educational program that references measurable learning objectives, such as detailed procedures for conducting biotechnology experiments. It is designed to be interactive, incorporating images and videos to achieve the desired outcomes in biotechnology education.

METHOD

This study was conducted in two approaches: the laboratory experiment examined the effects of specific treatments under controlled conditions, while the module development aimed to bridge basic research with applied research to discover, develop, and validate knowledge in a practically applicable manner (Sugiyono, 2013).

Research variables

The research variables in the organoleptic test are structured as follows: the independent variable is the variation in starter inoculum size in TKB, while the dependent variables encompass the color, aroma, taste, and texture of TKB across various treatments.

Production of tempe *koro benguk*

The production of tempe *koro benguk* is displayed in Figure 1.

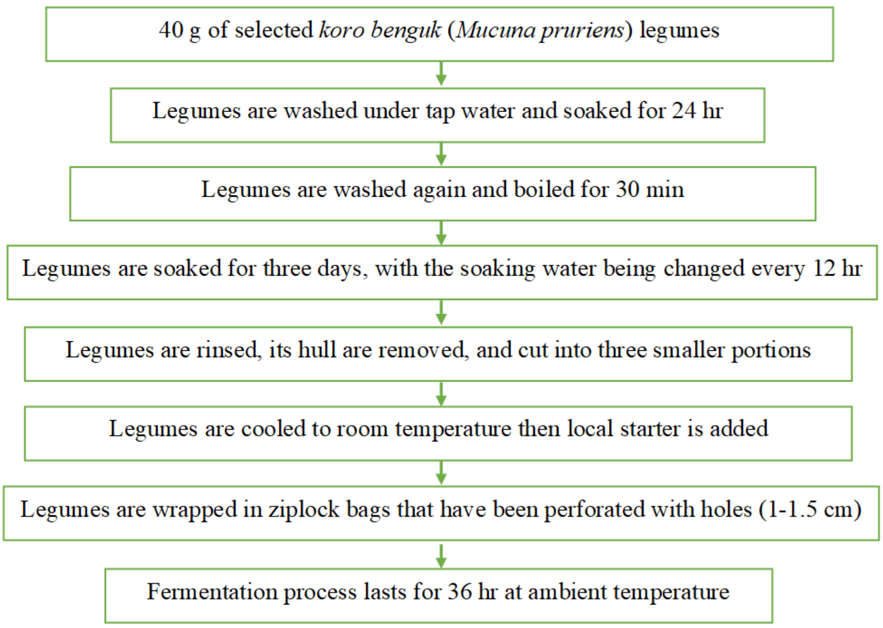

Figure 1. Steps in producing tempe *koro benguk* using local starter.

Treatment of different starter-to-substrate concentration

The starter is a crucial component in the production of TKB, following the *koro benguk* legumes. The molds or starter were prepared by drying TKB for two days until completely dry. Subsequently, it was finely ground and sieved to separate it from impurities. The treatments, involving different starter-to-substrate concentrations in TKB products, are presented in Table 1.

Table 1. Design of treatments using different starter-to-substrate concentrations

Treatments	Starter concentration (%) in substrate (40 g)
P1	0.05
P2	0.20
P3	0.30
P4	0.40
P5	0.50

Development of the biotechnology module

The laboratory procedures for producing TKB were structured and refined into an educational resources, as guided by Sugiyono (2013) in Table 2.

Table 2. Development stages of the biotechnology module

Indicator(s)	Description
Potential and issues	The research begins by identifying potential and issues related to the study's focus. Specifically, the development of a practical guide for TKB biotechnology at SMA Yadika 4 Jatiwaringin was initiated due to challenges highlighted by biology teacher Ms. Vica Pramesti Khusyaryanti, S.Pd. She reported past failed attempts at tempe-making practicals, where the mold failed to grow on the soybeans.
Information gathering	Information was collected to address the identified issues. It was found that the practical guide provided by the teacher lacked appeal, being plain and devoid of visuals or videos, which discouraged students from reading and understanding the material before starting the tempe-making practice.
Product design	The guide developed in this research includes diverse features such as images, videos, and relevant biotechnology facts, alongside step-by-step instructions for making TKB
Design validation	The guidebook was validated by lecturers from the Biology Education Program at Universitas Kristen Indonesia, as well as biology teachers and students from SMA Yadika 4 Jatiwaringin.
Design revision	Based on feedback from the validation process, weaknesses in the guide were identified and subsequently addressed by the researchers before the guide was distributed to Grade 10 students at SMA Yadika 4 Jatiwaringin.
Product testing	The trial of the TKB biotechnology guide was conducted in Class X-3 at SMA Yadika 4 Jatiwaringin, comprising 32 students. Students were first given the guide to study, followed by guided practical sessions in the biology laboratory. Afterward, they completed a questionnaire to evaluate the guide's effectiveness and usability.

Potential and issues

Potential and issues can serve as the starting point for research. There is potential for developing a biotechnology practical guide for TKB at SMA Yadika 4 Jatiwaringin.

Information gathering

This step serves as the foundation for addressing identified issues in the research. The author identified that the practical guide created by teachers lacked appeal, as it was presented plainly without images or videos. This presentation discouraged students from reading and understanding it before starting the tempe-making practical.

Product design

The product of this module development was designed in a visually appealing format that includes colors, images, videos, and factual information about biotechnology concepts and the process of producing TKB.

Design validation

The validation is conducted by faculty members in the Department of Biology Education at Universitas Kristen Indonesia, biology teachers, and students at SMA Yadika 4 Jatiwaringin.

Design improvement

Following the validation of the product design, weaknesses in the product become apparent. Therefore, improvements are necessary before the product is provided to the students at SMA Yadika 4 Jatiwaringin.

Product testing

This step was initiated upon receiving comments and suggestions by the experts, who specializing in language, content, and media. The purpose of this trial was to assess students' perceptions. Students were provided with the practical guide to study beforehand. They were then guided in making TKB in the biology laboratory. Subsequently, students were asked to fill out a questionnaire to provide feedback to the educators regarding their assessment of the biotechnology practical guide for TKB.

Data analysis

Experimental data

The statistical calculation to determine the percentage uses the following formula (Azahrah *et al.*, 2021):

$$P = \frac{F}{N} \times 100\%$$

Where :
P = Percentage,
F = Frequency, and
N = Total frequency of number of respondents.

The data analysis method used to obtain accurate and accountable conclusions is as follows:

$$\bar{x} = \frac{\Sigma n}{n}$$

Where:
$\bar{x}$ = Mean value,
Σn = Sum of values, and
N = Number of respondents.

Development data

Validation of practical guide

This study employs a Likert scale in statement form. There are four options classified as answer choices in the instrument. The indicator scores for statements range from 1 to 4: (1) very poor, (2) poor, (3) good, and (4) very good. The statistical calculation used by the author to determine the percentage was based on Azahrah *et al*. (2021).

$$P = \frac{F}{N} \times 100\%$$

Where :
P = Percentage,
F = Frequency, and
N = Total frequency of number of respondents.

The suitability of the TKB practical guide was evaluated by experts using a scale ranging from "very suitable" to "very unsuitable," based on Table 3. The descriptive statistics were also used to determine teacher's responses and students' perception towards biotechnology module. In addition, the criteria for validation by students were displayed in Table 4.

Table 3. Criteria for validation questionnaire scores (Sugiyono, 2013).

Average score range	Criteria
24% - 43%	Not suitable
44% - 62%	Moderately suitable
63% - 81%	Suitable
82% - 100%	Highly suitable

Table 4. Scoring of students' responses

Average score range	Criteria
0 – 20%	Very poor
20% - 40%	Poor
41% - 60%	Fairly good
61% - 80%	Good
81% - 100%	Very good

RESULTS AND DISCUSSION

a. Production of tempe *koro benguk* (*Mucuna pruriens*)

Preparation of local starter

The starter commonly used by the local community is in powder form. In Dimoro village, people typically use homemade local molds. The traditional production method remains simple. The starter or mold inoculum is essential in the fermentation process of tempe (Romulo & Surya, 2021; Teoh *et al.*, 2024). The mold spores in the starter may significantly affect the quality of the tempe (Castaneda *et al.*, 2024). The process of making local starter in Dimoro village involves cutting tempe into small cubes. These tempe cubes are dried under direct sunlight, usually for two days. Once dried, the tempe pieces are finely ground into powder. The tempe flour is sifted to separate it from impurities. Ready-to-use starter can be stored in the refrigerator to maintain its quality. Poor-quality starter is typically brown in color with a pungent odor. In contrast, a good starter is clean white in color with the characteristic aroma of tempe (Figure 2).

Figure 2. Starter of tempe *koro benguk* in dried powdery form.

The fermentation process of TKB is influenced by the dosage of the starter applied. The local starter is sprinkled onto boiled and steamed *koro benguk* legumes. The microbiota involved in soybean fermentation contributes significantly to the quality of the final product. The starter culture plays a crucial role in facilitating the biotransformation process of legumes, enhancing the final product quality, and ensuring the feasibility of the process for commercial development (Vinícius de Melo Pereira *et al.*, 2017; Elhalis *et al.*, 2024).

Excessive starter application may cause TKB to deteriorate rapidly, become sticky, turn black, and develop a bitter taste. Conversely, insufficient starter may lead to suboptimal fungal growth on the TKB, resulting in uneven white coloration, absence of the typical tempe aroma, a hard texture of the *koro* legumes, and a crumbly or non-compact texture. The optimal composition of the starter culture in TKB fermentation is a critical factor for the successful production of tempe. Starter cultures are essential for controlling fermentation, ensuring product consistency, and enhancing the digestibility, nutritional value, and sensory quality of tempe (Elhalis *et al.* 2024). Fermentation reduces the anti-nutritional factors in legumes. Microorganisms contribute through enzymatic reactions and various metabolic activities that improve the quality of legume-based products.

Surbakti *et al.* (2020) emphasized the importance of balancing the amount of the starter to achieve optimal fermentation, considering the quantity of soybeans processed into tempe. To address the issue of the hard texture of *koro benguk* beans due to suboptimal starter culture, several variations in starter concentrations were optimized. Wikandari *et al.* (2021) stated that in tempe products, fungal growth causes the beans to fuse together through fungal mycelium and its extracted enzymes, which facilitate the attachment of the mycelium to the bean surface, giving the product its typical appearance with a soft texture. Several enzymes detected in the fungus, such as proteolytic, lipolytic, amylolytic, other hydrolytic enzymes, and esterases which play similar roles in enhancing bean digestibility and producing volatile compounds, particularly aldehydes and alcohols (Mei *et al.*, 2007; Ghosh and Ray 2011).

Characteristics of tempe koro benguk

The starter concentrations used in this study were 0.05%, 0.2%, 0.3%, 0.4%, and 0.5% of the weight of 40 grams of ripe *koro benguk* legumes, wrapped in plastic. These concentrations were adjusted based on the previous studies (Rahayu *et al.*, 2019; Suwasono *et al.*, 2022). These starter proportions were intended to optimize the fermentation process of the typical TKB by Dimoro villagers. This allows the molds growing on TKB to thrive and propagate effectively. The results of adapting the same producing steps for TKB are presented in Table 5.

Table 5. Physical characteristics of tempe *koro benguk* from different treatments using starter concentrations and fermentation duration.

No	Fermentation duration	Starter conc. (%)	Physical characteristics
1	12 jam	0.05 0.20 0.30 0.40 0.50	Brown with typical *koro benguk* color, slightly firm texture, typical *koro benguk* aroma, tasty, not compact
2	24 jam	0.05 0.20 0.30 0.40 0.50	New mold growth starts, slightly firm texture, typical tempe aroma, tasty, somewhat compact
3	36 jam	0.05 0.20 0.30 0.40 0.50	White like fresh tempe, soft texture, slight sour aroma, tasty, compact

Table 5 indicates that the optimal fermentation duration for TKB is 36 hours. Tempe fermented for 36 hours exhibits a white color similar to fresh tempe, a soft texture, a slightly sour aroma, a delicious taste, and compact growth of yeast on the *koro* beans (Figure 3). In contrast, TKB fermented for 12 and 24 hours showed poorer color, aroma, texture, taste, and compactness. Romulo and Surya (2021) reported that tempe *koro benguk* tended to have a slightly bitter taste and a firmer and crispier texture compared to soybean tempe.

Figure 3. Physical appearances of tempe *koro benguk* fermented in 12-h (A), 24-h (B), and 36-h (C).

Table 6. Sensory attributes of tempe *koro benguk* by panelitsts.

Criteria	Starter concentration/ Score by panelists				
	0.05%	0.2%	0.3%	0.4%	0.5%
Color	70%	70%	73.3%	70%	50%
Aroma	76%	70%	73%	73.33%	70%
Texture	70%	70%	80%	73.33%	66.66%
Taste	66.66%	63.33%	66.66%	66.66%	63.33%

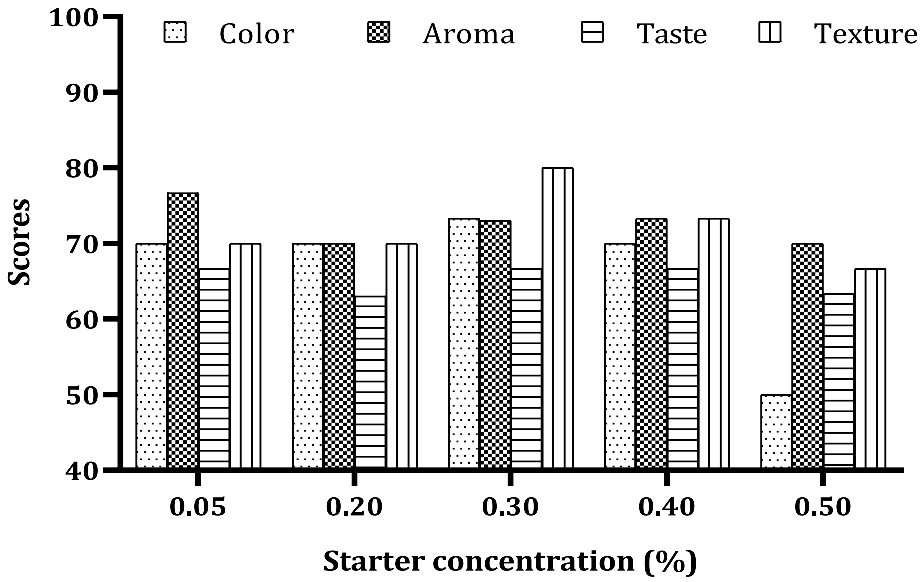

Figure 4. Organoleptic evaluation scores for tempe *koro benguk* made from different starter concentrations.

Organoleptic test

The optimal fermentation duration for TKB was determined to be 36 hours (Figure 4). This finding will serve as the basis for further study, where each package of tempe contains 40 grams of *koro benguk* mixed with local starter. Each treatment was then subjected to the organoleptic test. The organoleptic test was conducted by six panelists selected for their expertise in microbiology and biotechnology from Badan Riset dan Inovasi Nasional (BRIN) Cibinong, Bogor, Indonesia. The panelists assessed the characteristics of color, aroma, texture, and taste, and the results are detailed in Figure 4. Color plays a crucial role in the visual acceptance of a product and is an important factor in organoleptic testing (Muroki *et al.*, 2024). Unappealing color in food, even if it tastes good, can deter consumption due to the perception that it deviates from its expected color (Khalisa *et al.*, 2021). Color also serves as an indication of the success of the fermentation process in TKB. Successfully fermented tempe will appear white due to evenly distributed mold growth on the *koro* legumes. In contrast, suboptimal fermentation may result in uneven white color or even darkness due to contamination by other fungal species.

The uneven growth of fungi and contamination by other fungi during the fermentation process of TKB could be caused by insufficient hygiene at the production site. The results showed that the most preferred color of TKB by the panelists was observed at the starter concentration of 0.3%, scoring 73.33%, while the lowest score (50%) was given at the starter concentration of 0.5%. This preference may be attributed to the white color of TKB in this treatment, where the growth of *Rhizopus* spp. appears evenly distributed on the *koro benguk* legumes.

The assessment of a food product's aroma can be done by smelling the scent it emits. The odor produced can determine the food's aroma, which is crucial as it significantly influences consumer acceptance Khalisa et al., (2021). The aroma also serves as an indicator of the success of the fermentation process in TKB. Successful fermentation results in the distinct earthy aroma typical of tempe. This aroma is caused by the activity of the enzyme lipooxygenase, which reacts with fats inside soybeans or *koro* beans, hydrolyzing triglycerides and producing free fatty acids that are easily oxidized (Ciabotti *et al*., 2007). This reaction generates compounds responsible for the earthy aroma, including ethyl phenyl ketone (Bintanah *et al*., 2021).

Meanwhile, poor-quality tempe will have a sharp sour aroma similar to *tapai* (fermented cassava). The origin of this sour aroma in tempe is influenced by the duration of the fermentation process. Puspitasari *et al*. (2022) noted that in a 36-hour fermentation of tempe, a sharp sour aroma is still distinctly present. Regarding the aroma of TKB, the panelists gave the highest score (76.66%) for tempe with 0.05% of the starter concentration. The flavor profile involves the relationship between taste and aroma. One of the factors determining whether a food product is acceptable to consumers is its taste profile (Khalisa *et al*., 2021; Asiimwe *et al*., 2024). The taste can also serve as an indication of the success of the fermentation process in TKB. Poor-quality tempe will taste bitter and sour. Regarding taste, the panelists gave scores of no less than 70%, indicating that improvements are still needed to enhance consumer preferences in the future.

Regarding texture, it also serves as an indicator of the success of the fermentation process in TKB. Tempe *koro benguk* itself has a slightly firmer texture compared to soybean tempe. A good TKB will have a moderately firm texture that is still easy to chew, and when sliced with a knife, the legumes remain intact due to the binding action of the molds. In contrast, poor-quality TKB will have a very firm texture that is difficult to chew, and when sliced, the legumes will separate. This may be due to uneven mold growth, causing the legumes to dry out and become hard. Panelists gave the highest score (80%) to TKB with 0.3% of starter concentration.

b. Development of practical guidelines or biotechnology module based on the production of tempe *koro benguk*

The biotechnology module or laboratory guidelines for high school students is a product resulting from development research based on local wisdom from Dimoro village, specifically focusing on TKB. The development of this module follows the steps outlined in research and development (Sugiyono, 2013). Instruments utilized in this study include validation sheets and Google forms to assess student responses to the practicum guide.

Potential and issues

The initial phase of this study focused on exploring both the potential benefits and challenges to ascertain the need for developing practical guidelines for tempe *koro benguk*. This stage involved conducting interviews with local residents of Dimoro village and biology teachers at SMA Yadika 4 Jatiwaringin. Identifying potential issues serves as the foundation for the research. Potential represents the added value that can be utilized, while issues highlight discrepancies between expectations and actual occurrences. (Sugiyono, 2013).

The interviews were conducted on April 24, 2023, with preliminary information indicating that *koro benguk* plants are becoming scarce due to few residents utilizing the plant and considering it a weed or a habitat for snakes. *Koro benguk* plants are often cleared and discarded. Consequently, the local knowledge of producing tempe from *koro benguk* seeds is also diminishing. There are few successors among the younger generation in Dimoro village who know how to make tempe from *koro benguk*. Thus, the threat of losing this local wisdom is increasing.

Meanwhile, interviews with biology teachers from SMA Yadika 4 Jatiwaringin revealed that they have previously conducted biotechnology practicums involving tempe-making, but encountered failures where the mold did not grow on the soybeans or substrates. The issue was then connected to our goal of preserving and promoting the local wisdom of Dimoro village, particularly in the process of producing TKB, thereby equipping students with the proper techniques of tempe-making skills while also fostering the conservation of this invaluable local knowledge.

Information gathering

Based on the identified potential and issues, the next step is information gathering. This process aims to collect data intended to address the identified problems by planning for a specific product (Sukackė *et al.*, 2022). Kamuihkar *et al.* (2023) emphasize that learning media is a crucial component within the educational framework in schools. Subsequently, gathering reference sources from books, journals, and the internet will aid in developing the practical guide.

Product design

After obtaining the necessary data, the next stage is to design a laboratory manual. The design of this laboratory manual includes a cover page, preface, table of contents, list of figures, list of tables, learning objectives, material description, equipment and materials, procedures, evaluation, conclusion, and bibliography (Table 7).

Table 7. Product design.

Illustration(s)	Description(s)
1. Cover  	The practical guidelines or laboratory manual cover consists of a front and back cover. The front cover includes the title, subject matter, images of *Mucuna pruriens* legumes, and tempe made from the materials, class, authors, and supervising instructor prominently displayed on the front page. Meanwhile, the back cover contains a summary of the contents of the laboratory manual.
2. Preface 	The preface contains the author's expression of gratitude to those who assisted in the creation of the laboratory manual, requests for constructive criticism and suggestions, and the date of the manual's creation.

<table>
<tr><th>Illustration(s)</th><th>Description(s)</th></tr>
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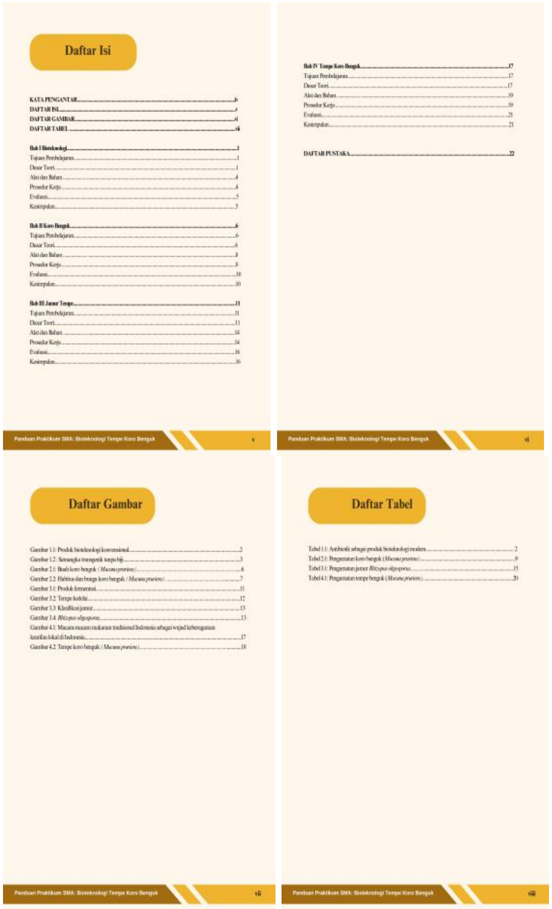
3. Table of contents



</td><td>The table of contents includes all chapter titles, sub-chapters, and content within the laboratory manual. The list of figures comprises all images present in the laboratory manual. The list of tables includes all tables found within the laboratory manual.</td></tr>
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4. Chapter

</td><td>The beginning of each chapter includes the chapter title, objectives of the practical, description of the material, and figures that provide the theoretical basis related to the practical title.</td></tr>
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5. Unique facts

</td><td>Unique facts are added to each chapter of the laboratory manual in the material description section. These unique facts serve to stimulate students' curiosity and broaden their insights into the practical material. Thus, students will better understand the material they are learning by connecting it to everyday life experiences.</td></tr>
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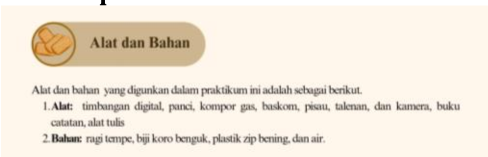
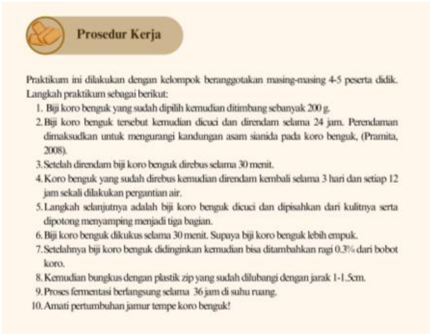
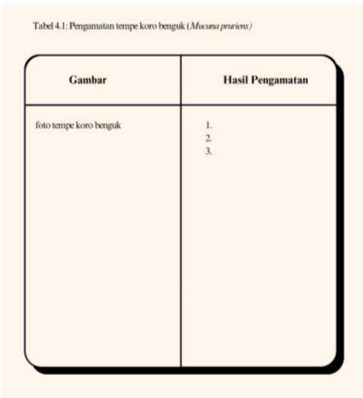
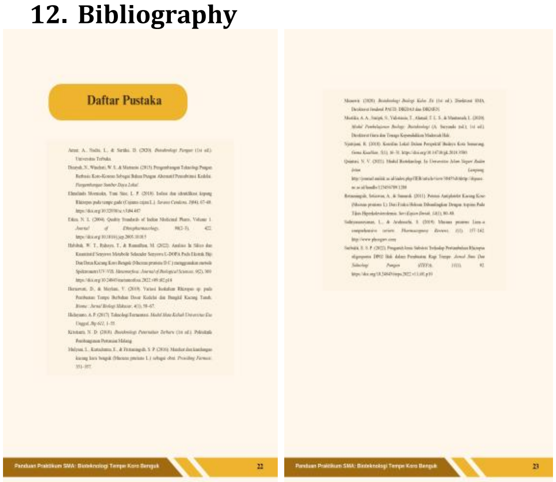
Illustration(s)	Description(s)
6. Preparation  Alat dan Bahan Alat dan bahan yang digunkan dalam praktikum ini adalah sebagai berikut. 1. **Alat:** timbangan digital, panci, kompor gas, baskom, pisau, talenan, dan kamera, buku catatan, alat tulis 2. **Bahan:** ragi tempe, biji koro benguk, plastik zip bening, dan air.	The equipment and materials section lists the equipment that students and teachers need to prepare for conducting the practical activities. This is to achieve the objectives outlined in the laboratory manual. These tools and materials will assist students in better preparing for the practical work.
7. Instruction  Prosedur Kerja Praktikum ini dilakukan dengan kelompok beranggotakan masing-masing 4-5 peserta didik. Langkah praktikum sebagai berikut: 1. Biji koro benguk yang sudah dipilih kemudian ditimbang sebanyak 200 g. 2. Biji koro benguk tersebut kemudian dicuci dan direndam selama 24 jam. Perendaman dimaksudkan untuk mengurangi kandungan asam sianida pada koro benguk. (Pramita, 2008). 3. Setelah direndam biji koro benguk direbus selama 30 menit. 4. Koro benguk yang sudah direbus kemudian direndam kembali selama 3 hari dan setiap 12 jam sekali dilakukan pergantian air. 5. Langkah selanjutnya adalah biji koro benguk dicuci dan dipisahkan dari kulitnya serta dipotong menyamping menjadi tiga bagian. 6. Biji koro benguk dikukus selama 30 menit. Supaya biji koro benguk lebih empuk. 7. Setelahnya biji koro benguk didinginkan kemudian bisa ditambahkan ragi 0.3% dari bobot koro. 8. Kemudian bungkus dengan plastik zip yang sudah dilubangi dengan jarak 1-1.5cm. 9. Proses fermentasi berlangsung selama 36 jam di suhu ruang. 10. Amati pertumbuhan jamur tempe koro benguk!	The procedure section provides the steps or methods for conducting the practical activities. Students can effectively carry out practical work by following these procedures correctly. The procedures are written in procedural sentences to ensure clarity and ease of understanding for students.
8. Supplementary media  	The laboratory manual includes practical activities presented through videos as a supplementary medium to facilitate students' understanding of the steps involved in the practical work. The practical videos feature audio, text, and images. Using practical videos can enhance students' interpersonal skills and abilities in the cognitive, affective, and psychomotor domains (Nurwahidah *et al.*, 2021).
9. Data format  Tabel 4.1: Pengamatan tempe koro benguk (*Mucuna pruriens*) Gambar: foto tempe koro benguk Hasil Pengamatan: 1. 2. 3.	The observation table contains images and students' observations on the practical product, which is tempe made from *M. pruriens*. This table assists students in observing the tempe they have prepared. It also serves as an example for students to complete their practical reports in their respective assignment books.
10. Evaluation sheet  Evaluasi 1. Mengapa jamur bisa tumbuh di biji koro benguk? 2. Tempe benguk yang sudah jadi akan berwarna putih. Jelaskan mengapa hal itu bisa terjadi!	The evaluation section contains questions that students answer. The purpose of this evaluation is to understand the weaknesses and level of achievement of students in a learning process (Idrus, 2019). This evaluation is important to assess whether students have understood the material taught after completing the practical work.

Illustration(s)	Description(s)
11. Conclusion 	The conclusion should align with the objectives of the practical work. It serves as a logical connection from deductive thinking to generalization rather than a summary or essence (Suryana, 2010). In this section, students are trained to draw conclusions from the practical work they have conducted.
12. Bibliography 	The bibliography contains the reference sources used by the researcher in creating the laboratory manual. These reference sources include books, modules, and scientific journals.

Design validation

This laboratory manual product has been validated by three expert validators and received feedback from a biology teacher at SMA Yadika 4 Jatiwaringin: Dr. Bintang Simbolon, M.Si., Adisti Ratnapuri, M.Pd., Riska Septia Wahyuningtyas, M.Pd., and Vica Pramesti Kusharyanti, S.Pd. The validation aims to ensure that the laboratory manual product can be piloted effectively after assurance that the initial product has been developed. Expert validation is crucial for identifying potential errors in language, ensuring material accuracy, addressing content deficiencies, and alignment with student needs during field testing of the product.

Media validation

The validation of the laboratory manual as a learning media was conducted by Riska Septia Wahyuningtyas, M.Pd., focusing on visual presentation and delivery aspects.

The evaluation results indicate that the media expert assessed this laboratory manual as "highly suitable" for evaluation items 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 14, 16, 17, 18, and 19 with a suitability score of 100%. This aligns with the assessment indicators of the laboratory manual, where the module's content size matches the material, there is a proportional font size for titles and content, clear paragraph separation, consistent layout, appropriate use of font types, suitable font variations, and clear and consistent heading levels. However, for evaluation items 4, 13, 15, 20, 21, 22, and 23, the laboratory manual was rated as "Suitable" with a suitability score of 75%. This was due to assessment indicators where typographical errors in content were still found. The quality of the media will generate interest among students during the biology learning process (Tpoenifu *et al.*, 2023; Syahfitri, 2024).

Subject validation

The suitability of the learning material in

The form of a laboratory manual was assessed by Dr. Bintang Simbolon, M.Si., focusing on visual presentation and delivery aspects. The assessment results indicate that the subject matter expert assessed this laboratory manual as "Highly Suitable" for evaluation items 1, 2, 3, 4, 5, 6, 7, 8, and 9 with a suitability score of 100%. This is in accordance with the assessment indicators of the laboratory manual, where clarity of sentence structure, communicative delivery of material, dialogical and interactive content, relevance to students' developmental stages for learning and understanding local wisdom, and proper use of language rules including grammar and spelling accuracy were considered.

Language or grammar validation

The linguistic suitability of the instructional material in the form of a laboratory manual was assessed by Mrs. Adisti Ratnapuri, M.Pd., focusing on visual presentation and delivery aspects. The assessment results indicate that the language expert evaluated this laboratory manual as "Suitable" for evaluation items 1, 2, 3, 4, 5, and 6 with a suitability score of 75%. This evaluation aligns with the assessment indicators of the laboratory manual, where the text on the cover adheres to the standard language rules, the description on the cover page is easily understood, the content is relevant to the teaching material, the language used is formal, and there is no ambiguity in interpretation. Virginia *et al*. (2023) also emphasize the importance of using appropriate language in educational materials, avoiding excessive word repetition, avoiding discriminatory content, ensuring communicative delivery of content, and using sentences that effectively convey information.

Educators' or teachers' responses

The instructional response in the form of the laboratory manual was evaluated by Vica Pramesti Kusharyanti, S.Pd., focusing on visual presentation and delivery aspects. The evaluation results indicate that the teacher rated this laboratory manual as "Highly Suitable" for evaluation items 1, 3, 6, 7, 9, 10, and 11 with a suitability score of 100%. This assessment aligns with the indicators of the laboratory manual evaluation, where the structure of the manual facilitates students' understanding of the material, the use of fonts, text, and sentences is clear and legible, contextual issues raised are appropriate for students' characteristics, the language used is easily understandable, and the selection of pictures, illustrations, and icons is appealing.

However, for evaluation items 2, 5, 8, 12, and 13, the laboratory manual received a rating of "Suitable" with a suitability score of 75%. This rating was attributed to difficulties encountered in applying the practical module in learning, particularly in the practical exercise of making tempe from *Mucuna pruriens*, a material that is rarely found.

Table 8. Comments and suggestions on biotechnology module.

No	Validator	Comments and suggestions	Actions
1.	Media expert	Many typos in the text. Already corrected. Enlarge the practical results table. Provide space for writing conclusions and participating in discussions. Final score = 75%	Implemented
2.	Language expert	Ensure consistency in the use of images; if animated, all images in the book should be animated. Already corrected. Improve color coordination on the cover; it is currently not very attractive. Final score = 75%	Implemented

Design revision

The laboratory manual on *M. pruriens* tempe biotechnology for high school students has undergone validation by subject experts and is now advancing to the revision stage based on the feedback provided by these experts. Identifying issues within the laboratory manual will guide researchers in making necessary improvements. The comments and suggestions from the expert validators are presented in Table 8. The module has been revised to address these issues.

Product trial

The laboratory manual was implemented for 10th-grade students at SMA Yadika 4 Jatiwaringin. The implementation aimed to gather students' perceptions regarding conventional biotechnology in *Mucuna pruriens* tempe production. According to Napitupulu *et al.* (2023), students' perceptions reinforce the validators' comments on the suitability of the learning material. The practical or laboratory session was conducted with Class X-3, comprising 32 students aged between 15 and 17 years old. The implementation involved providing the laboratory manual for students to study its contents. Students were then guided through one of the practical activities outlined in the manual, specifically the production of *M. pruriens* tempe. Before to the practical session, the researcher obtained an official permit from the school principal, Rahni Simbolon, S.Pd. Upon receiving permission, the practical session was scheduled for April 29th, 2024, at the Biology Laboratory of SMA Yadika 4 Jatiwaringin (Figure 5).

Figure 5. Product trial of biotechnology module to high school students. (A) Module and equipments, (B) Technical assistance, (C) Documentation, (D) Evaluation session.

One month before the start of the practical session, educators provided an overview of biotechnology, fungal biology, and *M. pruriens* to introduce the content and refresh students' memory on the laboratory manual. Following this introduction, educators guided the students in preparing the legumes and mastering microbiology techniques. After completing the practical session, students were invited to fill out an online questionnaire using Google Forms. The questionnaire aimed to gather students' perceptions regarding the laboratory manual, assessing the suitability of the content, practice questions, presentation, language, graphics, and illustrations. The students' responses are presented in Figure 6. The average suitability score was 73%. This aligns with the evaluation criteria of the laboratory manual, focusing on using clear and straightforward language, organizing material sequentially from the fundamentals of biotechnology to avoid student confusion, incorporating student interest in local knowledge concerning *M. pruriens* tempe, and providing practical content that relates closely to students' daily experiences (Utari *et al.*, 2023).

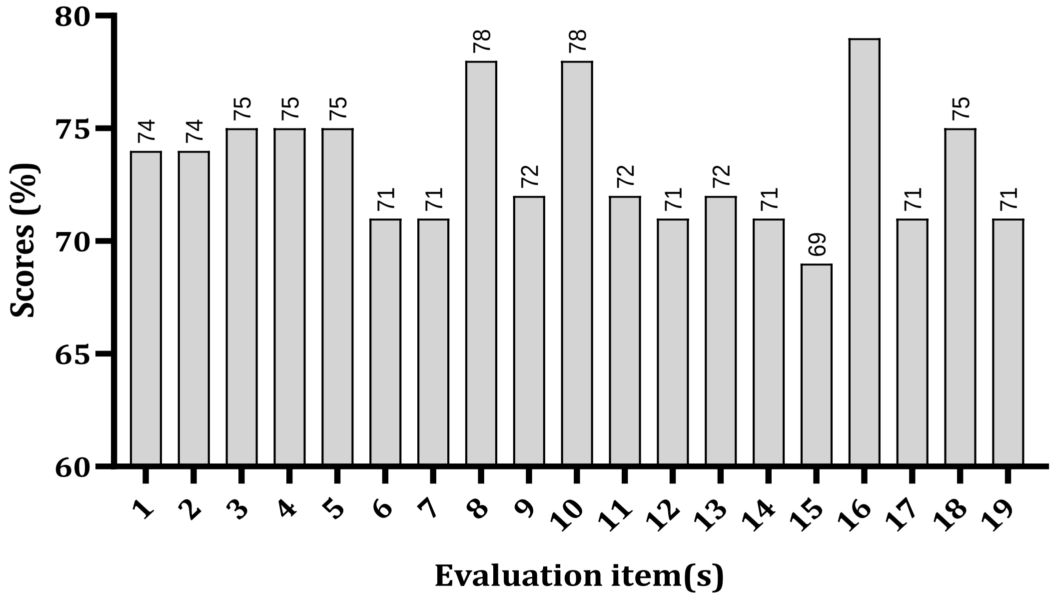


Figure 6. Students' responses after product trial.

CONCLUSION

The sensory evaluation of *M. pruriens* tempe using a local starter revealed that panelists preferred tempe with a 0.3% starter concentration due to its whiter color, better taste, and softer texture. In terms of aroma, panelists favored tempe with a 0.05% starter concentration as it exhibited a more typical aroma compared to other levels. The laboratory manual for *M. pruriens* tempe was found suitable for use, achieving an average score of 89% across language, content, and media validation criteria, rating it as "highly suitable." Teachers also responded positively, giving the manual an average score of 90% and a rating of "highly suitable." Similarly, students expressed a very positive perception of the manual, with an average score of 73% and a rating of "Suitable" based on their feedback. A more tangible impact requires long-term monitoring and a larger sample size of students to establish consistent trends in student capacity building and to assess the effectiveness of the learning module.

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