



Development of a pocket book on biopesticides extracted from chili peppers (*Capsicum annuum* L.) for controlling leafworm pests (*Plutella xylostella*)

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Abstract

The use of chemical pesticides has long-term impacts on both the environment and living organisms. One alternative to chemical pesticides is to replace them with biopesticides made from organic materials that are more environmentally friendly. The use of chili pepper (*Capsicum annuum* L.) waste is a potential solution because it contains capsaicin, which is toxic to leafworm pests (*Plutella xylostella*). Books on the use of rotten chili pepper waste as biopesticides are very limited and need to be developed so that the benefits of biopesticides can be utilized by the community. Developing this pocketbook also serves as a practical guide for the use of chili pepper biopesticides to control pests, thereby helping farmers reduce their dependence on chemical pesticides. The objective of this study is to describe the validity of the chili pepper (*Capsicum annuum* L.) biopesticide handbook for controlling leaf caterpillars. This type of research is development research with a qualitative and quantitative approach. The development method used is Educational Design Research (EDR), which includes the preliminary research stage, the prototyping phase, and the assessment phase, but in this study, it is limited to the prototyping phase. The data obtained is validity data for the handbook, collected through interviews with three validators, including subject matter experts, media experts, and language experts. This validity data was then analyzed descriptively. The validation results by the experts yielded a validity score of 84.6%, indicating that the book is suitable for use. Thus, the development of this pocketbook is expected to serve as a practical solution in supporting sustainable agriculture that is safer for the environment and human health.

Keyword: educational design research, pocket book, biopesticide, chili pepper

Abstrak. Penggunaan pestisida kimia memiliki dampak jangka baik terhadap lingkungan maupun terhadap makhluk hidup. Salah satu alternatif pengganti pestisida kimia tersebut adalah dengan menggantinya dengan biopestisida yang terbuat dari bahan organik yang lebih ramah lingkungan. Pemanfaatan limbah cabai rawit (*Capsicum annuum* L.) menjadi solusi potensial karena mengandung capsaicin yang bersifat toksik bagi hama ulat daun (*Plutella xylostella*). Buku mengenai pemanfaatan limbah cabai rawit busuk sebagai biopestisida ini sangat terbatas dan perlu dikembangkan agar manfaat biopestisida ini dapat digunakan oleh masyarakat. Mengembangkan buku saku ini juga sebagai panduan praktis pemanfaatan biopestisida cabai rawit untuk mengendalikan hama, sehingga dapat membantu petani mengurangi ketergantungan pada pestisida kimia. Tujuan penelitian ini adalah untuk mendeskripsikan validitas buku saku biopestisida cabai rawit (*Capsicum annuum* L.) untuk pengendalian hama ulat daun. Jenis penelitian ini adalah jenis penelitian pengembangan dengan pendekatan kualitatif dan kuantitatif. Metode pengembangan yang digunakan adalah Educational Design Research (EDR) yang meliputi tahapan pendahuluan (Preliminary Research), tahap pengembangan (Prototyping Phase), dan tahapan penilaian (Assessment Phase), namun dalam penelitian ini dibatasi sampai tahap pengembangan (Prototyping Phase). Data yang didapat merupakan data validitas buku yang diperoleh melalui angket wawancara terhadap tiga (3) orang validator yang meliputi ahli materi, media, dan bahasa. Data validitas tersebut kemudian dianalisis secara deskriptif. Hasil validasi buku saku oleh para ahli menghasilkan skor validitas 84,6%, yang menunjukkan bahwa buku ini layak digunakan. Dengan demikian, pengembangan buku saku ini diharapkan dapat menjadi solusi praktis dalam mendukung pertanian berkelanjutan yang lebih aman bagi lingkungan serta kesehatan manusia.

INTRODUCTION

The use of chemical pesticides in Indonesian agriculture remains relatively high and continues to increase in several regions. Previous studies have reported that the majority of farmers still rely heavily on chemical pesticides, with usage rates ranging from 82.5% to 88.19% in areas such as Central Java and other agricultural regions (Alim et al., 2018; Susanti & Wicaksono, 2018). Although sustainable agricultural practices, including Integrated Pest Management (IPM), have been introduced, approximately 74.44% of farmers continue to apply chemical pesticides routinely in crop cultivation (Sari et al., 2016). Excessive pesticide use not only contributes to environmental pollution and poses risks to human health but also increases production costs for farmers (Syafitri et al., 2021). Therefore, greater efforts are needed to reduce dependence on chemical pesticides through the promotion and adoption of environmentally friendly agricultural practices, such as botanical pesticides and organic farming techniques.

One natural biopesticide that has recently attracted increasing attention is bird's eye chili (*Capsicum annuum* L.). Khoerunisa et al. (2024) reported that bird's eye chili contains capsaicin, an active compound that functions as a botanical pesticide by disrupting the digestive system, growth, and nervous activity of insects, thereby increasing pest mortality, including that of the diamondback moth (*Plutella xylostella*), a major pest of mustard greens. Species within the *Capsicum* genus produce capsaicin, which induces dehydration in living tissues by attracting hydrogen atoms and stimulating water loss as a defensive mechanism. Furthermore, Zhang et al. (2023) explained that capsaicin induces physiological stress in insects through the activation of Transient Receptor Potential Vanilloid (TRPV) receptors, resulting in nervous system dysfunction, elevated metabolic activity, and ultimately death. In addition, capsaicin affects feeding behavior and reproductive performance, making it a promising biological control agent for sustainable agriculture. The advantages of bird's eye chili as a biopesticide include its widespread availability, relatively low cost, and simple preparation process. Nevertheless, its application requires caution because capsaicin is an irritant to human skin and eyes and may cause phytotoxic effects on crops when applied at inappropriate concentrations.

Preliminary observations revealed that the utilization of biopesticides derived from spoiled bird's eye chili waste remains largely unknown among the general public. The use of spoiled chili as a biopesticide not only provides an alternative means of pest control but also contributes to reducing organic waste that is otherwise discarded. Several previous studies have investigated the use of bird's eye chili as a botanical pesticide. For example, Natsir (2015) evaluated bird's eye chili extract as a botanical pesticide for controlling caterpillar pests attacking mustard plants (*Brassica juncea*). However, the findings were not subsequently developed into an educational pocketbook. Likewise, Nursam et al. (2016) examined the effectiveness of a botanical pesticide prepared from chili fruits (*Capsicum annuum* L.) combined with garlic bulbs (*Allium sativum* L.) against onion armyworm (*Spodoptera exigua* Hübner). Their study focused on evaluating the effectiveness of the botanical pesticide but did not produce an educational resource in the form of a pocketbook. Similarly, Christita and Suryawan (2018) investigated the effectiveness of papaya leaf (*Carica papaya*) and bird's eye chili (*Capsicum frutescens*) extracts as bioinsecticides in the cultivation of oyster mushrooms (*Pleurotus ostreatus*), yet their research also did not extend to the development of a pocketbook.

A review of these previous studies indicates that although the efficacy of bird's eye chili as a botanical pesticide has been widely investigated, the findings have not been translated into practical educational materials for community use. To disseminate knowledge regarding the utilization of spoiled bird's eye chili as a biopesticide, the development of a pocketbook is considered appropriate. A pocketbook was selected because of its compact size, portability, and ease of use. According to the Great Dictionary of the Indonesian Language (Kamus Besar Bahasa Indonesia, 2008), a pocketbook is a small-sized book designed to be conveniently carried in one's pocket. Meikahana and Kriswanto (2015) further described a pocketbook as a practical publication containing concise text and illustrations that serves as an accessible guide or source of information. In addition to providing guidance on controlling leaf caterpillar pests, the proposed pocketbook also introduces the utilization of spoiled bird's eye chili waste as a biopesticide, including appropriate preparation procedures and application dosages. It is expected to be easily understood by a broad audience, including homemakers, household heads, farmers, and other community

members. Therefore, this study aimed to develop and validate a pocketbook on the simple preparation of biopesticides from bird's eye chili (*Capsicum annuum* L.) extract for controlling leaf caterpillar pests.

RESEARCH METHODS

This study employed the Educational Design Research (EDR) model. According to Akker (2010), EDR can be viewed from two complementary perspectives: development studies and validation studies. From the development perspective, EDR aims to generate research-based solutions for addressing complex educational problems. In addition, it seeks to explore the characteristics of effective educational interventions and the processes involved in their design and development to facilitate successful implementation.

Plomp and Nieveen (2013) proposed that EDR consists of three phases: preliminary research, the prototyping phase, and the assessment phase. However, the present study was limited to the first two phases, namely preliminary research and the prototyping phase. The development process also incorporated Tessmer's (1993) formative evaluation, focusing on self-evaluation and expert review. As suggested by Zaini (2018), educational book development may concentrate on the development and expert validation stages. Accordingly, this study was confined to product development and expert validation. The resulting product was expected to achieve at least the "fairly valid" category based on the validity criteria proposed by Akbar (2022).

During the preliminary research phase, an initial needs assessment was conducted through problem analysis, identification of the need for developing the pocketbook, formulation of potential solutions, and an experimental study examining the effect of the developed biopesticide on the mortality of the diamondback moth (*Plutella xylostella*). The experimental findings served as the primary content for developing the initial prototype of the pocketbook.

During the prototyping phase, the pocketbook was developed using the experimental findings obtained in the previous phase. Subsequently, the research team conducted a self-evaluation to produce the initial prototype. This prototype was then submitted to three expert validators specializing in content, language, and instructional media for evaluation. The validation process involved iterative revisions based on feedback from both the expert review and self-evaluation stages until the final prototype was achieved. Self-evaluation was conducted by the research team to assess and refine the design of the pocketbook, whereas expert review involved independent evaluations by specialists in the relevant fields. Expert validation was conducted using a questionnaire based on a five-point Likert scale, with the validation instrument adapted from Lestari (2020) and Nurrahmi (2017). The validation data obtained from the three experts were analyzed descriptively using the validity criteria proposed by Akbar (2022), with the percentage score calculated using Formula 1. The validity criteria for the developed pocketbook are presented in Table 1.

$$V = \frac{TSe}{TSh} \times 100\% \dots \dots \dots \text{Formula 1}$$

Description:

V = Validity score (%)
TSe = Total validation score obtained from the validators
TSh = Maximum possible validation score

Table 1 Validity Criteria for the Developed Pocketbook

No.	Validity percentage	Validity level
1	85.01–100.00%	Highly valid; suitable for use without revision.
2	70.01–85.00%	Sufficiently valid; suitable for use with minor revisions.
3	50.01–70.00%	Less valid; not recommended for use and requires major revisions.
4	1.00–50.00%	Invalid; unsuitable for use.

(Source: Adapted from Akbar, 2022)

RESULTS AND DISCUSSION

Preliminary research

The development of the pocketbook entitled "Biopesticides from Spoiled Bird's Eye Chili Extract for Controlling Diamondback Moth (*Plutella xylostella*)" was carried out using the Educational Design Research (EDR) model and resulted in a validated educational product. The development process consisted of two main phases: preliminary research and the prototyping phase. During the preliminary research phase, initial observations, a needs analysis, a literature review, and an experimental study on the effectiveness of spoiled bird's eye chili biopesticide against the mortality of the diamondback moth (*Plutella xylostella*) were conducted. The findings from this phase are summarized in Table 2.

Table 2 Results of the Preliminary Research Phase

Stage	Findings
Initial observation	Bird's eye chili is one of the major agricultural commodities in South Kalimantan and is widely used in traditional Banjar cuisine. Due to surplus production, a considerable proportion of harvested chilies remains unsold and eventually spoils. These spoiled chilies represent a potential raw material for producing environmentally friendly biopesticides. In addition to reducing agricultural waste, the resulting biopesticide has the potential to control the diamondback moth (<i>Plutella xylostella</i>), a major pest of mustard greens, while minimizing environmental pollution associated with synthetic pesticides.
Literature review	The literature review indicated that no educational pocketbook specifically addressing the use of spoiled bird's eye chili as a biopesticide for controlling <i>P. xylostella</i> has been developed.
Needs analysis	The needs assessment demonstrated the necessity of developing a practical pocketbook to disseminate information on the preparation and application of spoiled bird's eye chili biopesticides.
Experimental study	Experimental results confirmed that biopesticides prepared from spoiled bird's eye chili significantly increased the mortality of the diamondback moth (<i>Plutella xylostella</i>). These findings subsequently served as the primary scientific content for the pocketbook.

(Source: Processed research data)

The preliminary research findings demonstrate both the practical need and scientific basis for developing the proposed pocketbook. Besides providing an environmentally friendly alternative for pest management, the product also promotes the utilization of agricultural waste, thereby supporting sustainable agricultural practices and environmental conservation.

Prototyping phase

The prototyping phase focused on designing, revising, and validating the pocketbook before publication. Product development followed Tessmer's formative evaluation, consisting of self-evaluation and expert review. The initial prototype was developed using the experimental findings obtained during the preliminary research phase. The pocketbook was designed in an A6 format (10 × 14 cm), following the recommended specifications for educational pocketbooks (Rahmah et al., 2023). During the self-evaluation stage, the research team critically reviewed the content, layout, and overall presentation, resulting in Prototype I (see Figure 1 (A)).

Prototype I represented the initial version of the educational product and was subsequently submitted for expert validation. The expert review involved three validators with expertise in content, language, and instructional media. Validation was conducted using a questionnaire adapted from Lestari (2020) and Nurrahmi (2017). The reviewers identified several aspects requiring improvement, including image quality, color selection, content completeness, institutional logos, publication year, and several layout components. In addition to assigning validation scores, the experts also provided constructive recommendations to improve the overall quality of the pocketbook. The validation results are presented in Table 3.

Table 3 Average Validation Scores of the Developed Pocketbook

Evaluation Aspect	Percentage	Validity Category
Content accuracy	84%	Sufficiently valid
Language	82%	Sufficiently valid
Design and illustrations	88%	Highly valid
Overall average	84.66%	Sufficiently valid

(Source: Processed research data)

Beyond the quantitative validation scores, qualitative feedback from the validators provided valuable recommendations for product improvement (see Table 4). These suggestions included revising the scientific classification, updating supporting references, improving image resolution, expanding the discussion of plant pests, correcting scientific nomenclature, refining typography and layout, reorganizing the glossary, strengthening the book title, adding publication information, incorporating relevant Qur'anic verses and their interpretations, updating classification references, italicizing scientific names according to nomenclatural conventions, and providing explanatory captions for QR codes. All recommendations were incorporated into subsequent revisions, resulting in the final version of the pocketbook.

According to the validity criteria proposed by Akbar (2022), the pocketbook achieved an overall validity score of 84.66%, indicating that it is sufficiently valid and suitable for implementation with only minor revisions. Zaini (2018) emphasized that expert validation serves as an essential procedure for evaluating the feasibility of educational products prior to implementation. Likewise, Istiqamah and Hazimi (2025) argued that expert validation ensures that educational materials satisfy established quality standards before being used in learning environments. Figure 1 (B) presents the final prototype of the pocketbook, which was produced after the research team conducted a final self-evaluation incorporating all revisions recommended during the expert review.

Table 4 Summary of Expert Review Feedback and Revisions

Validator	Recommendations	Revisions made
Content Expert	Updated the taxonomic classification using recent and authoritative references.	Taxonomic classification was revised based on up-to-date scientific references.
	Expanded the description of bird's eye chili by including cultivation practices, environmental requirements, plant benefits, and growth conditions.	Additional references and comprehensive explanations were incorporated.
	Improved the quality and relevance of chili plant images.	High-resolution images relevant to the content were substituted.
	Expanded the discussion of plant pests, particularly the diamondback moth (<i>Plutella xylostella</i>), supported by additional references.	The pest section was revised and enriched with updated scientific information.
Language Expert	Replaced the section title Foreword with Preface.	The section title was revised accordingly.
	Removed unnecessary underlining from taxonomic classifications.	Formatting was corrected.
	Reviewed and updated the scientific names according to current nomenclature standards.	Scientific names were revised following the latest taxonomic conventions.
	Arranged the glossary entries alphabetically.	The glossary was reorganized in alphabetical order.
Media Expert	Emphasized the biopesticide theme in the book title.	The title was revised to better reflect the book's main topic.
	Removed the phrase "Compiled by" from the cover page.	The cover design was simplified accordingly.
	Added the publication date and author team information to the preface.	The requested information was incorporated.
	Included Qur'anic verses and their interpretations relevant to the book content in the table of contents.	Relevant Qur'anic verses and interpretations were added.
	Increased the font size of the Qur'anic verse headings.	Typography was improved for better readability.
	Updated taxonomic references using recent scientific literature.	Recent references were incorporated into the classification section.
	Formatted all scientific names in italics according to nomenclature conventions.	Scientific names were italicized throughout the book.
	Added explanatory captions to all QR codes.	Captions were included for each QR code.

(Source: Processed research data)



Figure 1 (A) Cover of pocketbook prototype I; and (B) Cover of the final pocketbook prototype (in Indonesian)

Content, language, and media validation

The validation results indicate that the developed pocketbook met the minimum validity requirements for educational materials, achieving an overall validity score of 84.66%, which falls within the "sufficiently valid" category according to Akbar (2022). This finding suggests that the pocketbook is suitable for implementation following minor revisions recommended by the expert validators.

Content validation

The content validation yielded a score of 84%, indicating that the pocketbook possesses adequate content validity. The validators agreed that the material was consistent with the objectives of the pocketbook, scientifically accurate, well organized, and presented in a manner that was both engaging and easy to understand. In addition, the material was considered comprehensive, relevant to the intended topic, and capable of broadening readers' knowledge while avoiding content that could potentially violate ethical, cultural, or human rights principles.

The experts nevertheless recommended several improvements, including updating taxonomic classifications using recent references, expanding the discussion of bird's eye chili cultivation and its environmental requirements, improving image quality, and providing a more comprehensive description of plant pests, particularly the diamondback moth (*Plutella xylostella*). These recommendations were incorporated into the revised version of the pocketbook. The findings are consistent with Syamsurizal et al. (2021), who emphasized that the validity of instructional materials is strongly influenced by the completeness, systematic organization, and scientific accuracy of the presented content. Well-developed educational materials should also be supported by relevant illustrations and supplementary information that facilitate readers' understanding of complex concepts.

Language validation

The language aspect obtained a validity score of 82%, which also falls within the "sufficiently valid" category (Akbar, 2022). The validators considered the language to be grammatically appropriate, clear, concise, and suitable for the target audience. The terminology was used consistently, sentence structures were easy to comprehend, and spelling, punctuation, glossary entries, and reference formatting generally complied with

accepted language conventions. Several revisions were recommended, including replacing the introductory section title, correcting the formatting of scientific names, removing unnecessary underlining in taxonomic classifications, and arranging glossary entries alphabetically. These revisions enhanced the readability and linguistic consistency of the final product.

Language quality plays a critical role in determining the effectiveness of educational materials because it directly influences readers' comprehension. Ibrahim (2015) argued that learning resources should employ standard language and well-structured sentences to ensure that educational messages are communicated clearly. Similarly, Rahmi et al. (2022) suggested that instructional materials should use straightforward, interactive, and communicative language appropriate to learners' cognitive development. Furthermore, Pratama et al. (2021) highlighted that typography—including font selection, size, and consistency—significantly affects readability and learners' comfort during the learning process. Collectively, these findings emphasize that both linguistic accuracy and visual readability contribute substantially to the effectiveness of printed educational media.

Media validation

The media aspect received the highest validation score (88%), placing it in the "highly valid" category (Akbar, 2022). The validators positively evaluated the visual appearance of the pocketbook, including the cover design, color composition, typography, illustration placement, image clarity, and overall layout. These elements were considered visually attractive and appropriate for supporting the presentation of the instructional content. Several improvements were nevertheless suggested during the validation process, including emphasizing the biopesticide theme in the title, simplifying the cover page, adding publication information, incorporating relevant Qur'anic verses and interpretations, updating classification references, providing captions for QR codes, and ensuring that all scientific names followed standard nomenclature conventions. These recommendations were implemented in the final version of the pocketbook.

According to Arsyad (2018), an effective combination of colors and visual elements enhances the realism of instructional media and attracts readers' attention from the first encounter. Likewise, visual texts should employ simple and legible typography while avoiding excessive variation in font styles. Sutrisno and Puspitasari (2021) further reported that well-designed educational books improve learning effectiveness by facilitating comprehension and increasing learner engagement. Similarly, Susilana and Riyana (2018) argued that printed instructional media integrating high-quality illustrations, clear explanations, and relevant scientific terminology are more effective in communicating information and stimulating learners' interest in reading. Overall, the validation findings indicate that the developed pocketbook satisfies essential standards of content quality, linguistic appropriateness, and instructional media design, making it suitable for subsequent implementation following minor revisions. The revisions suggested by the validators further improved both the scientific quality and visual presentation of the product, thereby increasing its potential as an educational resource.

Educational value and potential applications of the developed pocketbook

Unlike conventional textbooks, the developed pocketbook adopts a compact A6 format (10 × 14 cm), making it highly portable and convenient for everyday use. This format is consistent with the definition of a pocketbook provided by the Great Dictionary of the Indonesian Language (Kamus Besar Bahasa Indonesia, 2008), which describes it as a small-sized book designed to be easily carried and accessed whenever needed. The concise format enables users to obtain essential information without the complexity commonly associated with larger instructional materials.

In addition to its portability, the pocketbook integrates concise explanations with relevant illustrations, thereby facilitating readers' understanding of both the theoretical and practical aspects of preparing botanical biopesticides. Rahmah et al. (2023) emphasized that educational pocketbooks are more effective when textual information is complemented by visual representations, as this combination enhances comprehension and learner engagement. Similarly, Mardatillah (2018) described pocketbooks as practical printed learning resources characterized by concise language, systematic organization, and a focus on a single topic, making them particularly suitable for independent learning.

The expert validation results demonstrate that the developed pocketbook satisfies the fundamental requirements of educational media in terms of content quality, language, and visual design. According to Akbar's (2022) validity criteria, the overall validation score of 84.66% indicates that the product is sufficiently valid and appropriate for use following minor revisions. Feedback from expert validators was incorporated into the final version, resulting in improvements to scientific accuracy, readability, and visual presentation.

Nevertheless, the validation results should be interpreted within the scope of product feasibility rather than educational effectiveness. As stated by Thiagarajan et al. (1974), expert validation serves to establish the appropriateness of a product prior to field implementation but does not provide evidence regarding its practicality or effectiveness in real learning environments. Therefore, although the developed pocketbook can be considered suitable for pilot implementation, further empirical studies are required to evaluate its practicality, usability, and impact on learning outcomes.

The findings suggest that the pocketbook has considerable potential as an alternative learning resource for higher education courses such as Plant Physiology and Horticulture, particularly in Biology and Agriculture programs. Furthermore, its practical format makes it suitable for broader community use, including farmers, students, and the general public interested in sustainable agricultural practices. The pocketbook provides comprehensive guidance on preparing biopesticides from spoiled bird's eye chili waste, appropriate application procedures, and scientific evidence regarding their effectiveness against the diamondback moth (*Plutella xylostella*).

Beyond its educational function, the pocketbook also promotes environmentally responsible agricultural practices by encouraging the utilization of organic waste as a value-added resource. This aligns with the principles of sustainable agriculture and environmental education, as it introduces an accessible, low-cost, and eco-friendly alternative to synthetic pesticides. Consequently, the product serves not only as an instructional resource but also as a medium for disseminating scientific knowledge that may encourage wider community adoption of environmentally sustainable pest management practices.

CONCLUSION

This study developed a pocketbook entitled "Biopesticides from Spoiled Bird's Eye Chili Extract for Controlling the Diamondback Moth (*Plutella xylostella*)" using the Educational Design Research (EDR) approach. The development process was limited to the preliminary research and prototyping phases and incorporated Tessmer's formative evaluation, including self-evaluation and expert review. Expert validation involving specialists in content, language, and instructional media resulted in an overall validity score of 84.66%, indicating that the pocketbook is sufficiently valid and suitable for use following minor revisions. The revisions improved the scientific content, language accuracy, and visual presentation of the product, enhancing its quality as an educational resource. The developed pocketbook has the potential to serve as an alternative learning resource for Biology and Agriculture education while also providing practical guidance for farmers and the wider community on the preparation and application of environmentally friendly biopesticides from spoiled bird's eye chili waste. However, this study was limited to expert validation and did not evaluate the product's practicality or instructional effectiveness. Future research should therefore investigate these aspects through field implementation involving the intended users to determine the educational impact of the pocketbook in authentic learning contexts.

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