ENHANCED KNOWLEDGE IN SCIENCES AND TECHNOLOGY
e-ISSN: 2773-6385

EKST

Vol. 5 No. 2 (2025) 411-423
https://publisher.uthm.edu.my/periodicals/index.php/ekst

Basic Analysis of the National Biotechnology Policy 2.0 Survey (SDB 2.0): An Overview

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DOI: https://doi.org/10.30880/ekst.2025.05.02.049

Article Info

Received: 26 February 2025
Accepted: 4 July 2025
Available online: 19 December 2025

Keywords

Biotechnology, Policy, Survey, Society, Data Analysis

Abstract

This study investigates public perceptions and awareness of biotechnology in Malaysia, focusing on the impact of the National Biotechnology Policy 2.0 (NBP 2.0). Conducted through a structured survey administered via Google Forms, the research gathered responses from 200 respondents, including researchers, industry professionals, policymakers, and educators. Results indicate significant awareness and positive attitudes towards biotechnological innovations across key sectors outlined by NBP 2.0: agricultural biotechnology, healthcare, and industrial biotechnology. Specifically, 85% of respondents recognized the potential of biotechnology to enhance agricultural productivity and food security. In healthcare, 78% acknowledged biotechnology's role in advancing medical treatments and wellness solutions. Additionally, 72% of respondents viewed industrial biotechnology as crucial for economic sustainability. Concerns regarding ethical implications and regulatory frameworks were also noted, reflecting a nuanced understanding across diverse demographic profiles. Quantitative and qualitative analyses underscore the policy's potential to address global challenges and inform evidence-based decision-making to foster public trust in biotechnology advancements.

1. Introduction

In the dynamic landscape of modern science, biotechnology stands as a beacon of innovation, offering solutions to some of humanity's most pressing challenges. From advancements in healthcare to sustainable agriculture and environmental conservation, biotechnological breakthroughs have the potential to reshape societies and economies on a global scale [1] [2]. As the world navigates complex issues such as climate change, food security, and healthcare access, the role of biotechnology becomes increasingly paramount in addressing these multifaceted challenges [3]. In a collaborative effort between the Faculty of Applied Sciences and Technology at Universiti Tun Hussein Onn Malaysia (UTHM) and the Malaysian Chapter of the Asian Federation of Biotechnology (AFOB-MC), a comprehensive survey is currently underway to gauge the level of awareness among respondents regarding the empowerment of

the biotechnology sector through the National Biotechnology Policy 2.0: Towards a Bioinnovative Society. Launched in September 2022, the National Biotechnology Policy 2.0 (NBP 2.0) focuses on three main pillars: agricultural biotechnology and food security, healthcare and wellness, and industrial biotechnology and economic sustainability. These pillars underscore the multifaceted impact of biotechnology on various sectors of society, emphasizing its potential to address pressing global challenges [4].

Against this backdrop of scientific advancement and societal transformation, understanding of public perceptions and attitudes towards biotechnology becomes imperative. The "Survey Dasar Bioteknologi 2.0" (SDB 2.0) emerges as a crucial tool, offering insights into the nuanced perspectives of Malaysians towards biotechnological applications within their socio-cultural context. Drawing upon recent developments in the field of biotechnology, the SDB 2.0 survey seeks to build upon previous studies and provide updated insights into public perceptions and awareness of biotechnology in Malaysia. Focusing on two key sections, the survey endeavors to unravel the intricate tapestry of Malaysian society's relationship with biotechnology. Section A: Demographic-Grounded in the foundational principles of demographic analysis, Section A serves as the cornerstone of the survey. By capturing essential demographic information from respondents, including age, gender, education level, and socioeconomic status, this section lays the groundwork for a comprehensive understanding of the diverse perspectives shaping Malaysia's biotechnological landscape [5]. Perspectives on the field of Biotechnology in Malaysia at the heart of the survey lies in next section, which delves into the intricate web of perceptions, attitudes, and beliefs surrounding biotechnological advancements in Malaysia. Through eight carefully crafted questions, this section navigates the terrain of public sentiment, exploring topics ranging from genetic engineering and healthcare innovations to environmental sustainability and ethical considerations [6].

This research paper presents the findings of the SDB 2.0 survey, shedding light on the demographic characteristics of respondents in Section A and their perceptions of biotechnology in Malaysia in Section B. The remainder of this paper will delve into the methodology used for conducting the survey, present key findings, discuss implications, and offer concluding remarks and suggestions for future research directions. This study endeavours to achieve the following objectives measure the level of awareness regarding the importance of biotechnology among respondents following the launch of NBP 2.0. Provide a platform for respondents to express their views on the necessity of biotechnology in addressing global challenges. Overall, this research aims to contribute to the ongoing dialogue on public perceptions of biotechnology and to inform evidence-based decision-making processes aimed at fostering public trust and acceptance of biotechnological innovations

2. Conceptual Framework of the Study

The study's conceptual framework is designed to explore the factors influencing public perceptions of biotechnology under Malaysia's National Biotechnology Policy 2.0 (NBP 2.0). It incorporates key determinants that have been identified in the literature as significant influences on how individuals perceive and engage with biotechnological innovations. Educational attainment plays a crucial role in shaping individuals' understanding and perception of biotechnology. Research indicates that higher levels of education are associated with greater scientific literacy, critical thinking skills, and a more nuanced understanding of complex technological issues [7] [8]. In the context of biotechnology, individuals with higher educational backgrounds are likely to have access to more detailed information about biotechnological advancements, including their potential benefits and ethical implications. This knowledge base enables them to form informed opinions and attitudes toward biotechnological applications under NBP 2.0. For instance, [7] found that individuals with higher educational levels tend to accept biotechnological innovations more due to their enhanced understanding of scientific principles and their implications for societal progress. This understanding is crucial for policymakers and educators aiming to promote public engagement and acceptance of biotechnological advancements in Malaysia.

Media plays a significant role in shaping public perceptions of biotechnology by framing issues, highlighting benefits, and raising ethical concerns [6]. Different media platforms, including traditional news outlets, social media, and educational resources, influence how biotechnological innovations are portrayed to the public. Positive and balanced media coverage can enhance public trust and acceptance, whereas negative or sensationalized reporting may contribute to misconceptions and scepticism. According to [6], media exposure significantly influences public attitudes toward biotechnology by framing issues such as genetically modified organisms (GMOs) and gene editing technologies. Biased or inaccurate reporting can lead to public distrust, whereas transparent and informative communication can foster informed decision-making and support for biotechnological policies.

The conceptual framework is grounded in empirical research highlighting the multifaceted influences on public perceptions of biotechnology. Educational attainment influences individuals' understanding and acceptance of scientific innovations [7] [8]. Media exposure shapes public discourse and perceptions of biotechnology [6]. This framework guides the study in examining how these factors interact to influence public perceptions of biotechnology under NBP 2.0 in Malaysia. By exploring these relationships, the study aims to provide insights into effective strategies for enhancing public awareness, trust, and support for biotechnological innovations, contributing to evidence-based policy development and societal acceptance.

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3. Method

3.1 Research Design

This study utilized a cross-sectional survey design to assess public perception and awareness of biotechnology in Malaysia following the implementation of National Biotechnology Policy 2.0 (NBP 2.0). A structured questionnaire was developed to gather quantitative data on demographic information, awareness levels of NBP 2.0, and attitudes towards biotechnological advancements in agriculture, healthcare, and industrial sectors. The target population for this study included residents of Malaysia who are 18 years or older, representing a diverse cross-section of society including urban and rural areas. Respondents from various demographic groups were selected to ensure representation from different age groups, genders, educational backgrounds, and occupational sectors.

3.2 Survey Instrument

A structured questionnaire was developed using Google Forms. The questionnaire was divided into two sections: demographic information, which collected data on respondents' backgrounds, including age, gender, education, profession, and affiliation. The second section focused on the biotechnology sector in Malaysia, specifically on respondents' opinions, awareness, and perceptions regarding NBP 2.0. The questionnaire incorporated a mix of closed-ended questions with predefined response options and open-ended questions to capture qualitative insights

3.3 Sampling

The target population comprised respondents involved in the biotechnology sector, including researchers, industry professionals, policymakers, and educators. A stratified random sampling technique was employed to ensure representation from each category.

3.4 Sample Size

The survey aimed to collect responses from a total of 200 respondents. This sample size was determined to provide a meaningful representation of the larger population while considering practical constraints.

3.5 Data Collection

The survey was distributed through multiple channels, including email invitations, social media platforms, and direct outreach to relevant organizations. Respondents were assured of the confidentiality of their responses, and the purpose of the survey was clearly communicated.

3.6 Data Analysis

For quantitative analysis, descriptive statistics, including frequencies, percentages, and means, were employed to summarize demographic data and responses to closed-ended questions. - Inferential statistics, such as chi-square tests or t-tests, were used to identify relationships and patterns in the data. On the other hand, qualitative analysis, which is thematic analysis, was applied to open-ended responses to identify recurring themes and patterns.

4. Results and Discussion

This section presents and discusses the findings of the study based on the data collected through the survey. The discussion is organized according to key themes derived from the objectives of the research. First, the demographic profile of the respondents is outlined to provide context to their responses. This is followed by a detailed analysis of public awareness and perceptions of biotechnology applications in four major areas: (i) agriculture and food security, (ii) health and well-being, and (iii) industrial development and economic sustainability. The final subsection highlights suggestions and feedback provided by respondents regarding the implementation and promotion of biotechnology in Malaysia. Each section combines quantitative results with interpretative discussion to provide insights into the current level of public understanding and acceptance of biotechnology, particularly in the context of the National Biotechnology Policy 2.0.

4.1 Demographic Results

This section presents the demographic profile of the 77 respondents who participated in the survey. Understanding the background of the respondents including their state of residence, gender, age group, marital status, education level, employment sector, and preferred sources of biotechnology information is essential for interpreting the overall findings of the study. These demographic variables provide critical context that influences public perception, awareness, and engagement with biotechnology. The summary shown in Fig. 1 offers a visual representation of how

respondents from different backgrounds access biotechnology-related information, highlighting distinct communication patterns.

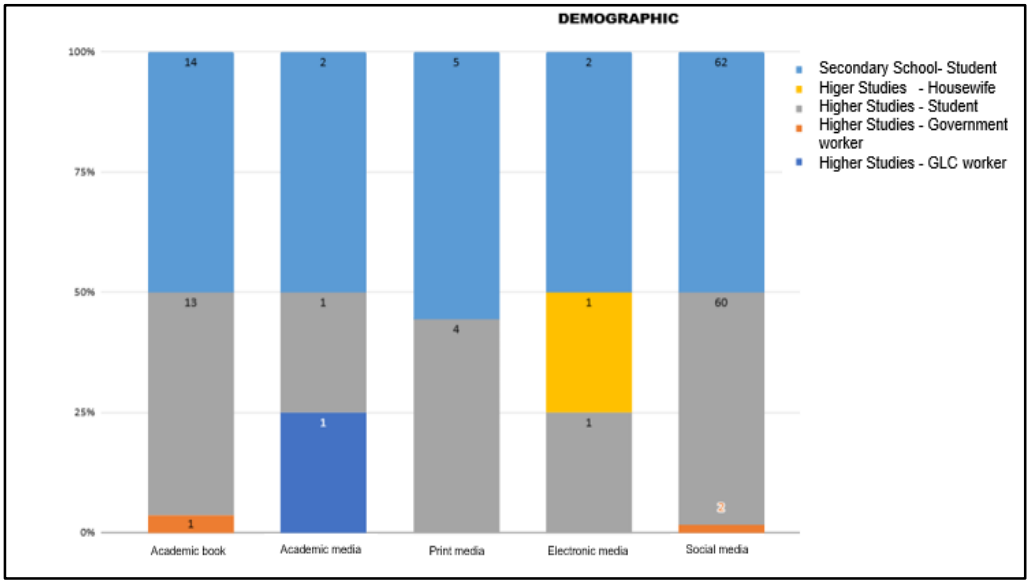

Fig. 1 Demographic result

The statistics from the 77 respondents polled reveal key demographic trends across state, gender, age, marital status, education, employment, and sources of reference material. A notable majority of participants were from Johor, with 69 replies (89.6%) coming from this state. This strong representation may be attributed to the presence of targeted biotechnology awareness programs and education-based initiatives in Johor, such as the BioDesa Johor programme, collaborations with Universiti Teknologi Malaysia (UTM), and biotechnology-related initiatives within the Iskandar Malaysia Bioeconomy Corridor. These initiatives have actively promoted science, technology, and innovation among local communities, particularly through partnerships with academic institutions and youth outreach. Selangor received seven responses, while Pahang recorded one, highlighting a less dense but still meaningful geographic reach.

In terms of gender, 64.9% of respondents identified as male, while 35.1% were female. This indicates a gender imbalance in survey participation. This male dominance could reflect higher engagement in online surveys among male youth or a broader pattern where men are more represented in science and technology-related public engagement activities [9]. However, the significant presence of women respondents suggests meaningful contributions from both genders. Research shows that women often bring unique perspectives in areas such as family health, ethical considerations, and community engagement important themes in biotechnology discussions [10]. Age-wise, the distribution was heavily concentrated in the 16–24 age group, which accounted for 67 responses (87%). This reflects effective outreach to younger individuals, possibly due to their greater exposure to online platforms and institutional networks such as schools and universities. Existing research supports this, noting that Malaysian youth are more responsive to digital and social communication strategies when engaging with science and innovation topics [9]. Smaller participation from the 25–34, 35–44, and 45–60 age groups provide a modest generational spread and reflects potential gaps in outreach beyond student populations. The data showed a broad spectrum of reference sources, with social media platforms (Facebook, Telegram) being the most prominent. This trend underscores the dominance of digital media in shaping knowledge acquisition. Traditional sources like brochures and academic books also played a role, and some respondents cited educators, policymakers, and schools as sources of information. The reliance on digital channels highlights the importance of digital literacy and critical evaluation skills when navigating online information on science and biotechnology [11].

When viewed through the lens of occupation, which is visualized in Fig. 1, distinct trends in media consumption become apparent. Students, particularly those still in secondary school, overwhelmingly accessed biotechnology information via social media, with 62 out of 77 respondents choosing this channel. This preference aligns with their age and familiarity with digital communication, confirming that younger, school-going individuals are highly influenced by content shared on platforms like Facebook and Telegram. Meanwhile, individuals engaged in higher education or professional sectors such as GLC or government workers show a more diversified use of information sources, including electronic media, academic media, and print media. This variation underscores how occupational roles influence the channels through which individuals engage with science content. Students are more digitally inclined and drawn to informal, fast-paced platforms, whereas professionals possibly due to their work environment or the need for validated information engage more with structured media sources. These findings align with broader literature that emphasizes how occupational settings and information needs shape how people access

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and interpret science-related information [12]. For example, government and GLC employees may rely on academic or institutional communication due to workplace norms and expectations.

The survey findings reveal that respondents' access to biotechnology information is influenced by multiple demographic factors, including state, gender, age, marital status, education level, and occupation. Youth, especially students from Johor, dominated the responses, with a strong preference for social media as an information source. While younger and unmarried individuals leaned toward digital platforms, professionals and higher-educated respondents accessed more formal channels like academic and electronic media. These trends highlight the need for targeted communication strategies that cater to different groups based on their background and media preferences.

4.2 Perspectives on the Field of Biotechnology in Malaysia

Section B of the poll as per shown in Fig. 2 offers a visual representation of which focuses on thoughts about biotechnology in Malaysia, asked respondents about their acquaintance with and perspectives on the National Biotechnology Policy (NBP) 2.0 aimed at fostering a bio-innovative society. The replies were mixed, with some showing strong agreement or support for the policy and others expressing ambiguity or disagreement. Notably, some respondents indicated a lack of acquaintance with the policy, using comments such as "Not Sure." This variety of replies indicates that the questioned populace has a range of viewpoints on the NBP 2.0 and its goals in encouraging bioinnovation within Malaysian society. It emphasizes the importance of understanding public views and awareness in driving policy implementation and increasing involvement in the biotechnology sector [5][6].

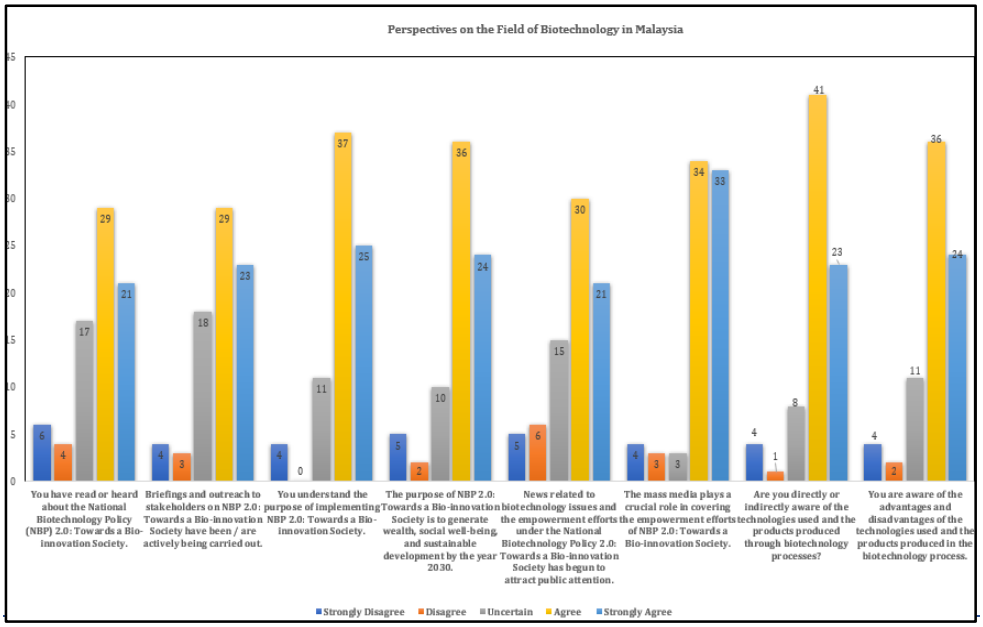

Fig. 2 The results of perspectives on the field of biotechnology in Malaysia

In this section, focusing on respondents' impressions of the Malaysian Biotechnology Policy (MBP) 2.0, respondents expressed varied degrees of agreement or disagreement with the idea of actively promoting and implementing the policy to build a bio-innovative society. Responses ranged from extreme disagreement to strong agreement, with some expressing confusion. The research reveals mixed feelings about the effectiveness and development of efforts targeted at advancing biotechnology in Malaysia. While some actively support initiatives towards a bio-innovative society, others have reservations or hold conflicting viewpoints. The diversity of perspectives underlines the complexity of public perceptions towards biotechnology regulations and the necessity for continual engagement and communication to address concerns and build consensus for the growth of biotechnological endeavours in the country [13]. When analysing respondents' knowledge of the objectives of the National Biotechnology Policy (NBP) 2.0, a range of responses emerged, from high agreement to significant disagreement. While some demonstrated clear understanding and support for the policy's goal of establishing a bio-innovation society, others were unclear or disagreed. This variation in replies reveals potential discrepancies in awareness or understanding of the policy's aims and implementation strategies. The presence of respondents who strongly agreed or agreed highlights some alignment with the envisioned trajectory of NBP 2.0, but those who expressed confusion indicate a need for further education on the issue. Respondents who strongly disagreed or disagreed may have different viewpoints on the feasibility or desirability of establishing a bio-innovation society as indicated in NBP 2.0. These varied viewpoints emphasize the importance of comprehensive communication and

engagement strategies to ensure broader understanding and consensus-building around biotechnology policies and initiatives in Malaysia [14] [15].

In this section on Malaysian biotechnology perceptions, respondents were asked about their thoughts on the National Biotechnology Policy (NBP) 2.0's objectives, specifically its goal of fostering a bio-innovation society and generating wealth, social well-being, and sustainable development by 2030. The replies varied, with some highly agreeing or agreeing with NBP 2.0's aims, reflecting an optimistic attitude about its ability to drive socioeconomic improvement through biotechnological advancements. Others indicated ambiguity or disagreement, possibly due to concerns about the policy's viability or effectiveness in achieving its stated goals. Respondents' perspectives on the attention generated by biotechnology-related news and empowerment activities related to the National Biotechnology Policy (NBP) 2.0, which aims at a bio-innovation society in Malaysia, demonstrate a variety of viewpoints. While some strongly agreed or agreed that such news has begun to attract public attention, reflecting a perceived rise in knowledge and interest in biotechnological developments and legislative measures, others were unsure or disagreed about the extent of public attention. These diverse replies indicate disparities in knowledge levels, media viewing patterns, and perceptions of the importance of biotechnology-related news and policy activities in driving public conversation and involvement.

Respondents' perspectives on the role of the media in reporting on the empowerment initiatives of the National Biotechnology Policy (NBP) 2.0, which aims at fostering a bio-innovation society, differed, but the majority expressed strong agreement or agreement. These replies indicate an awareness of the media's critical role in distributing information and creating awareness about programs promoting bio-innovation in Malaysia. Those who strongly agreed or agreed likely view the media as a vital platform for emphasizing the importance of NBP 2.0 and advocating for its success. In contrast, some respondents' confusion may suggest a lack of clarity or understanding of the media's influence or effectiveness in advancing NBP 2.0 objectives. Additionally, a few respondents disagreed or strongly disagreed, possibly indicating scepticism regarding the media's ability to accurately portray NBP 2.0 initiatives or its overall significance in shaping public opinion on biotechnology-related issues.

4.3 Biotechnology in Agriculture and Food Security

This section presents public perceptions regarding the application of biotechnology, particularly in the areas of agriculture and food security in Malaysia. Figure 3 illustrates the results, highlighting varying levels of awareness, acceptance, and confidence among respondents towards biotechnological advancements, especially in relation to genetically modified (GM) food products. Overall, the findings indicate a strong inclination towards agreement or strong agreement on the benefits of biotechnology, with only minimal levels of uncertainty or disagreement. The responses suggest a generally positive public outlook on the role of biotechnology in improving agricultural productivity, supporting food sustainability, and contributing to environmental and economic benefits.

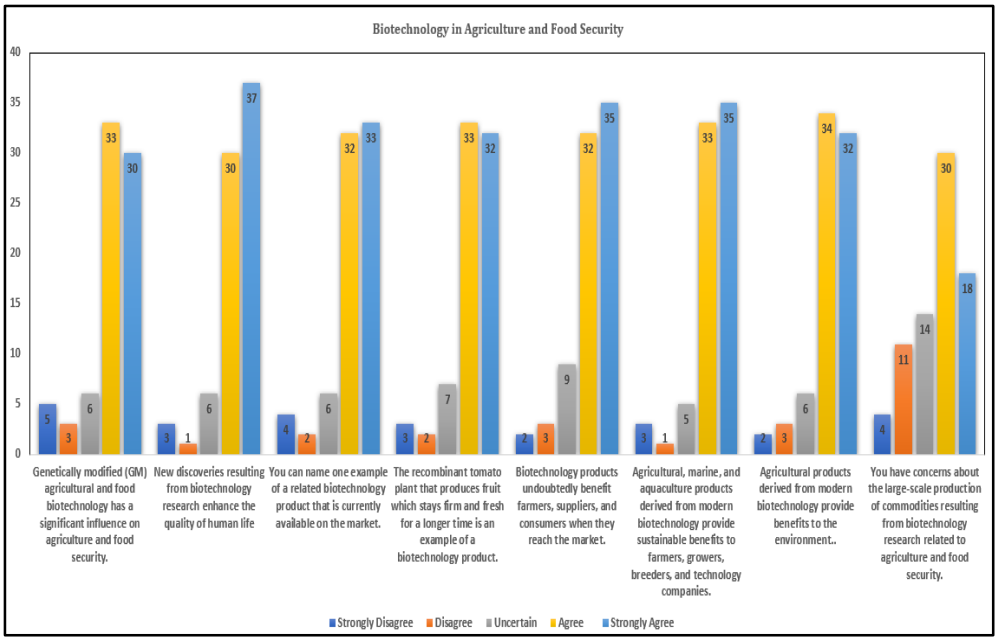

Fig. 3 The results of biotechnology in agriculture and food security

In the realm of agriculture and food security, particularly concerning genetically modified (GM) food, biotechnology has elicited a diverse range of responses from respondents in Malaysia. A predominance of views supports or strongly supports the use of biotechnology, with the majority of respondents indicating agreement or

strong agreement. This reflects a positive inclination towards the use of this technology in enhancing agricultural yields and ensuring food security. However, there are also a number of respondents who are uncertain or even express disagreement with the use of biotechnology in the context of agriculture and food. Further information on sample selection, survey methodology, and a deeper understanding of the factors influencing public attitudes towards biotechnology could provide a more nuanced context regarding the observed variations in viewpoints [16]. Based on the responses gathered, there is a strong inclination towards the belief that new discoveries stemming from biotechnological research significantly enhance the quality of human life within the realm of agriculture and food security in Malaysia. Out of 77 respondents, a majority expressed either agreement or strong agreement with this notion, indicating widespread endorsement of the positive impact biotechnology can have on improving agricultural practices, ensuring food safety, and ultimately elevating living standards. Despite some uncertainty reflected by a portion of respondents, the overwhelming consensus leans towards the affirmative, highlighting the perceived importance and potential benefits of biotechnological advancements in addressing crucial challenges related to agricultural sustainability and food security in the Malaysian context [17] [13].

Survey responses indicate strong support for biotechnology-related products in the market, particularly in agriculture and food security in Malaysia. A substantial number of respondents expressed either agreement or strong agreement, reflecting a positive outlook towards the utilization of biotechnology in enhancing agricultural practices and ensuring food security. Although some respondents expressed uncertainties, the overwhelming consensus leans towards acceptance and endorsement of biotechnological innovations in addressing agricultural challenges and bolstering food production capabilities. The lack of dissenting opinions suggests a prevailing sentiment of optimism and confidence in the efficacy and benefits of biotechnological advancements within the agricultural sector. The significant level of support for the integration of biotechnology into agricultural practices highlights its perceived value and potential contributions towards achieving food security objectives in Malaysia [14] [15]. The responses indicate general agreement towards recombinant tomato products yielding slow-ripening and fresh fruits as an example of biotechnological products in agriculture and food security in Malaysia. The overwhelming majority of respondents expressed varying degrees of agreement, indicating a consensus on the perceived efficacy or acceptance of such biotechnological interventions in enhancing agricultural produce quality and food security measures within the Malaysian context. However, a few respondents expressed uncertainty and a minority disagreed, suggesting some level of scepticism or lack of confidence in the stated assertion. Despite this, the predominant trend indicates a positive outlook towards the role of biotechnology, particularly in the context of agricultural enhancement and food security initiatives in Malaysia [18] [5].

A considerable number of respondents show predominantly strong agreement regarding the beneficial impact of biotechnological products in the agricultural and food security sectors in Malaysia. With a significant majority expressing strong agreement or agreement, it implies a widespread consensus on the notion that biotechnological products bring benefits to farmers, suppliers, and consumers when available in the market. This level of agreement underscores the perceived value and potential advantages associated with integrating biotechnology into agriculture and food security initiatives. However, a notable number of respondents express uncertainty, suggesting a need for further clarification or exploration of the implications and effectiveness of biotechnological solutions within these sectors. Additionally, a minority of respondent's express disagreement, indicating some scepticism regarding the purported benefits of biotechnological products in this context. Nonetheless, the overall trend of agreement among respondents highlights a general positive outlook on the role of biotechnology in enhancing agricultural practices and ensuring food security in Malaysia [16]. Survey responses indicate that a significant majority of respondents, totalling 68 individuals, express strong agreement or agreement regarding the sustainable benefits derived from modern biotechnology in agriculture, marine products, and aquaculture for farmers, agriculturalists, breeders, and technology companies. Out of these respondents, 56 strongly agree, 9 agree, and 3 express uncertainties, while none disagree or strongly disagree. This overwhelming consensus highlights the perceived value and impact of biotechnological advancements in enhancing agricultural productivity, ensuring food security, and supporting various stakeholders within these sectors [17] [13].

Based on the survey responses, there is overwhelming agreement among respondents regarding the benefits of agricultural outcomes derived from modern biotechnological sources to the environment. With a total of 78 respondents expressing agreement, 13 expressing uncertainty, and only 2 expressing disagreement, there is strong consensus recognizing the positive environmental impacts associated with the application of biotechnology in agriculture. This consensus likely stems from the potential of biotechnology to enhance crop resilience, reduce the need for harmful pesticides and fertilizers, and promote more sustainable farming practices. The majority opinion reflects a collective acknowledgment of biotechnology's role in fostering environmental stewardship within Malaysia's agricultural sector, indicative of a favourable attitude towards the integration of biotechnological innovations for ensuring both food security and environmental sustainability in the country [14][15]. Survey responses indicate considerable uncertainty regarding the production of large-scale commodities resulting from biotechnology research in agriculture and food security in Malaysia. While a significant portion of respondents express agreement, with some strongly agreeing, there are notable levels of uncertainty and disagreement scattered throughout the responses. This suggests a mixed perspective on the potential efficacy and impact of biotechnological

interventions in addressing agricultural and food security concerns. Further analysis is necessary to understand the underlying reasons for these divergent viewpoints and to inform future strategies in integrating biotechnology within the agricultural sector to ensure food security in Malaysia [16].

4.4 Health and Well-Being Care

Fig. 4 presents the results concerning public perceptions of biotechnology's role in healthcare and overall well-being in Malaysia. The data reflects a predominantly positive sentiment, with a strong consensus among respondents who agree or strongly agree that modern biotechnology significantly enhances healthcare services, supports national health security, and contributes to improved diagnosis and treatment. These views suggest widespread recognition of biotechnology's impact through applications such as pharmaceuticals, vaccines, and medical diagnostics. However, a minority of respondents expressed uncertainty or disagreement, indicating varying levels of understanding or concern regarding the integration of biotechnology into Malaysia's healthcare system. Overall, the results underscore growing public support and confidence in the potential of biotechnology to improve health outcomes and elevate the standard of medical care across the nation.

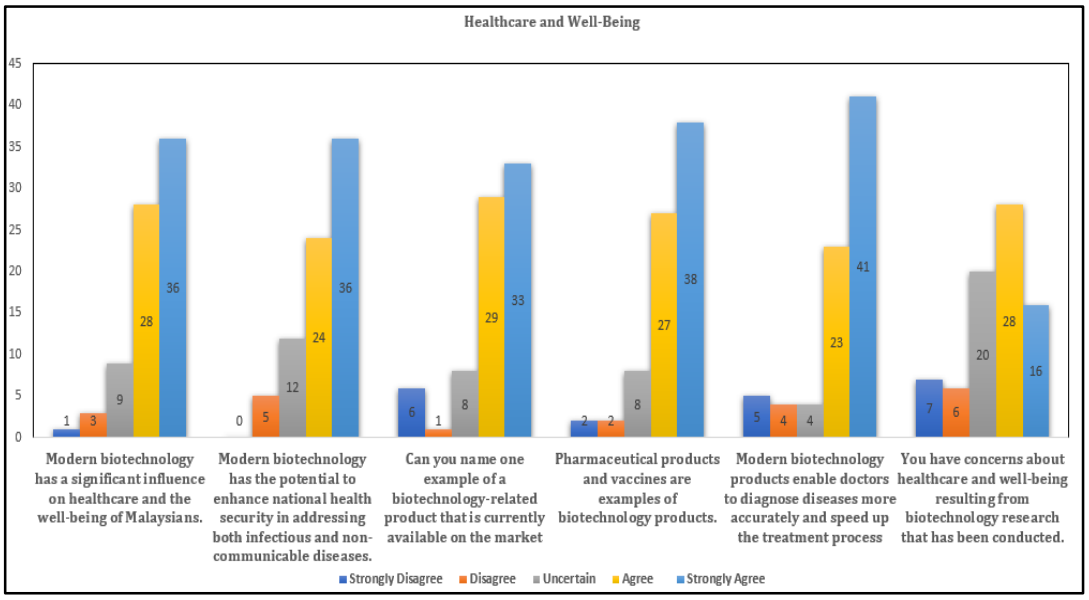

Fig. 4 The results of health and well-being care

Based on the responses, it appears that there is a strong consensus regarding the significant impact of modern biotechnology on healthcare and well-being in Malaysia. The majority of respondents either strongly agree or agree with this statement, with only a few expressing uncertainty or disagreement. This indicates a widespread belief in the transformative potential of biotechnology in enhancing healthcare services and ensuring the welfare of the Malaysian population. The high level of agreement suggests a recognition of the various applications of biotechnology, ranging from pharmaceuticals to medical diagnostics, in addressing health challenges and improving overall quality of life. However, it's worth noting that a small minority expressed disagreement or uncertainty, possibly indicating differing perspectives or concerns regarding the integration of biotechnological advancements in the healthcare system [18]. Based on the responses provided, it is evident that there is predominant agreement among respondents regarding the capacity of modern biotechnology to enhance national health security in addressing both communicable and non-communicable diseases in Malaysia. Out of the total number of respondents, a significant majority expressed strong agreement and agreement towards this notion, with only a small fraction remaining uncertain or disagreeing. This overwhelming support suggests a widespread recognition of the potential of biotechnology in bolstering healthcare and welfare measures within the country, reflecting a positive outlook towards its utilization in combating various health challenges [16] [5]. Survey responses indicate a predominantly positive outlook towards biotechnology-related healthcare products in Malaysia. A significant number of respondents, ranging from agree to strongly agree, expressed confidence and support for these products, indicating a favourable perception of their effectiveness and value in maintaining health and well-being. However, it is worth noting that there were also some respondents who expressed uncertainty or disagreement. Despite these dissenting views, the overall sentiment suggests a general acceptance and endorsement of biotechnological healthcare products within the Malaysian context [17] [13]. Based on the responses from a significant number of respondents, there is a strong consensus, with a majority indicating agree to strongly agree, regarding pharmaceutical products and vaccines being examples of biotechnological products within Malaysia. This agreement likely stems from the widespread acknowledgment of the integral role biotechnology plays in the

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development and production of such healthcare-related products. However, there are also a notable number of respondents who express uncertainty about this assertion, suggesting a potential gap in understanding or varying perspectives on the classification of pharmaceuticals and vaccines as biotechnological products. Nonetheless, the overall trend indicates a general acceptance and recognition of the biotechnological nature of these crucial healthcare interventions within the Malaysian context [14][15].

Survey responses indicate overwhelming agreement towards the notion that modern biotechnology products facilitate improved disease diagnosis and expedite treatment processes within the healthcare sector in Malaysia. The consensus is predominantly skewed towards strong agreement and agreement, indicating a widespread acknowledgment of the positive impact biotechnological advancements have on healthcare. This alignment of perspectives underscores the recognition of biotechnology's role in enhancing healthcare delivery by enabling more accurate diagnosis and hastening treatment procedures. While a small fraction of respondents' expresses uncertainty or disagreement, the prevailing sentiment underscores the significant potential of biotechnological innovations in bolstering healthcare systems, thereby advocating for continued integration and development of such technologies within Malaysia's healthcare landscape [18]. Based on the responses from a significant number of respondents, there is a mixture of opinions regarding the impact of biotechnology research on healthcare and well-being in Malaysia. A considerable portion expresses uncertainty about this matter, indicating a lack of clarity or information regarding the potential effects. However, among those who hold a stance, there is a notable division, with a substantial portion strongly agreeing or agreeing that biotechnology advancements positively contribute to healthcare and well-being. This suggests confidence or belief in the potential benefits of biotechnological innovations in improving healthcare services and overall welfare. Conversely, there are also respondents who strongly disagree or disagree, indicating scepticism or concerns regarding the implications of biotechnology in this context. This range of viewpoints highlights the complexity and diversity of perspectives within the Malaysian community concerning the intersection of biotechnology with healthcare and well-being [16].

4.5 Industrial Development and Economic Cycles

Fig. 5 illustrates public perceptions regarding the role of modern biotechnology in supporting industrial development and influencing economic cycles in Malaysia. The responses reflect a generally optimistic view, with many participants recognizing biotechnology's potential to transition Malaysia from a technology consumer to an innovator and producer of high-value biotechnological products. Respondents also show strong agreement on biotechnology's contributions to economic growth through enhanced research and development (R&D), employment generation, and technology transfer. While a portion of respondents express uncertainty or scepticism, the overall trend suggests widespread belief in biotechnology's capacity to strengthen Malaysia's industrial competitiveness and long-term economic sustainability.

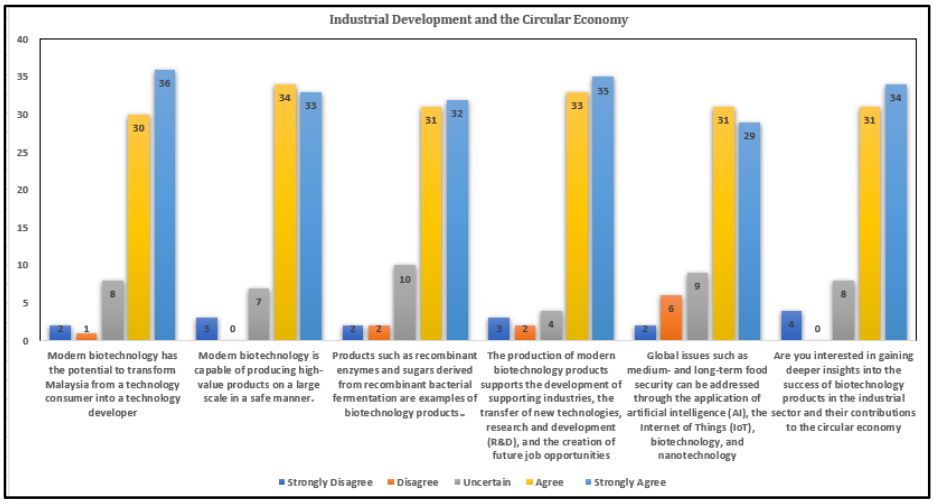

Fig. 5 The result of industrial development and economic cycles

According to survey responses, there is a widespread belief among participants in Malaysia regarding the transformative potential of modern biotechnology. Many respondents strongly agree or agree that biotechnology can elevate Malaysia from being merely a technology user to becoming a developer of cutting-edge technologies. This perspective indicates a strong optimism about biotechnology's role in advancing Malaysia's technological prowess. However, the presence of uncertainty and dissenting opinions among some respondents suggests varying levels of confidence or scepticism in biotechnology's transformative impact [16][17]. Opinions vary significantly regarding whether modern biotechnology can effectively produce high-value products at scale in Malaysia. While a majority of respondents express strong agreement or agreement with this capability, there are also indications of

uncertainty and a minority who strongly disagree. This diversity of opinion underscores both the perceived potential and the challenges or doubts surrounding biotechnological advancements in Malaysia. Overall, there is an overarching optimism about biotechnology's ability to contribute to large-scale product generation, despite reservations expressed by some respondents [13][18].

The survey highlights a significant agreement among respondents regarding specific examples of biotechnology products in Malaysia, such as recombinant enzymes and sugars derived from biotechnological processes. This consensus reflects a positive outlook on biotechnology's practical applications in Malaysia's industrial and economic sectors. However, there is also acknowledgment of uncertainty or disagreement among some respondents, indicating differing perspectives on the categorization and impact of biotechnological products [14][15]. Respondents overwhelmingly agree on the pivotal role of biotechnology in Malaysia's economy, particularly in fostering supporting industries, facilitating technology transfer, stimulating research and development (R&D), and generating employment opportunities. This consensus underscores the belief that biotechnology can drive innovation and economic growth. Nevertheless, some respondent's express uncertainty or disagreement, suggesting potential areas of scepticism or differing viewpoints on the economic impacts of biotechnological advancements [19][20]. There is a prevalent belief among respondents that advanced technologies including AI, IoT, biotechnology, and nanotechnology can effectively address global challenges such as food security. Many respondents strongly agree or agree with this view, indicating confidence in technological solutions to mitigate complex issues. However, the presence of uncertainty among some respondents highlights varying perspectives on the effectiveness and implementation of these technologies in addressing global challenges [21]. Finally, the survey reveals a positive outlook on the success of biotechnology products in Malaysia's industrial sector and their potential impact on economic cycles. Despite some uncertainty expressed by a minority of respondents, the majority supports the idea that biotechnology can drive industrial growth and positively influence economic dynamics. This viewpoint reflects optimism about the role of biotechnology in enhancing Malaysia's industrial competitiveness and economic sustainability [22] [23].

4.6 Suggestions

Fig. 6 presents qualitative insights from respondents regarding key areas where biotechnology plays a vital role in Malaysia's national development. The suggestions span across multiple sectors, reflecting the public's recognition of biotechnology's broad impact. Respondents highlighted biotechnology's critical contributions to agriculture, food security, healthcare, environmental sustainability, and economic growth. In addition, the importance of strengthening education, research, and responsible innovation was emphasized as essential to sustaining long-term advancements in biotechnology. These perspectives underscore the multifaceted value of biotechnology and offer guidance for strategic focus areas to enhance its implementation and societal benefits in Malaysia.

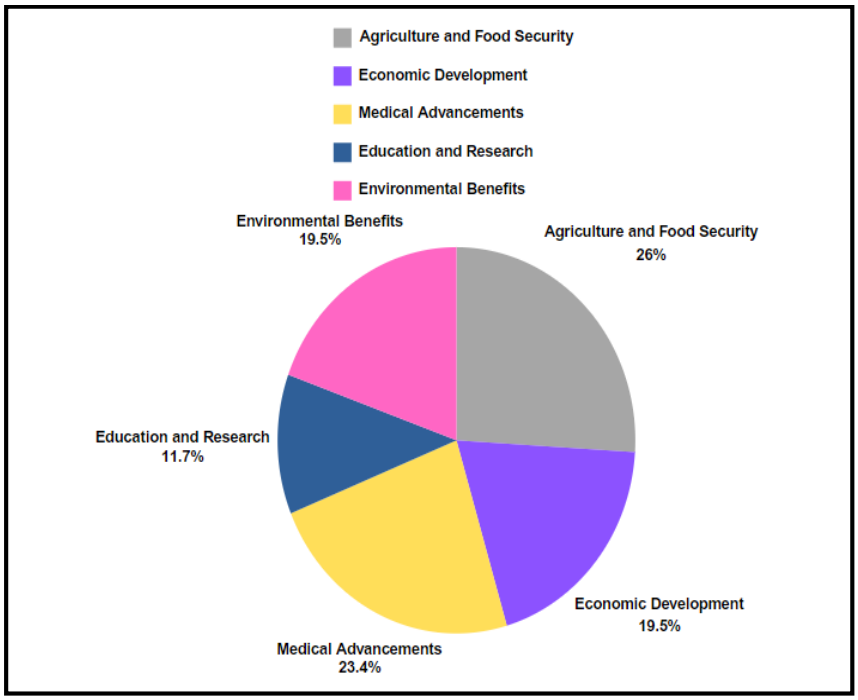

Fig. 6 Suggestions based on the importance of biotechnology in Malaysia's

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Twenty respondents highlighted the critical role of biotechnology in addressing agricultural and food security challenges. They cited advancements like genetically modified crops, precision agriculture, and biofortification for enhancing food yields, nutritional value, and resistance to pests and diseases. Biotechnology was also noted for promoting sustainable agriculture by reducing reliance on chemical inputs, conserving soil and water, and mitigating environmental impacts. Eighteen respondents underscored biotechnology's revolutionary impact on healthcare. They discussed its applications in developing new drugs, gene therapies, diagnostic tools, and personalized medicine. Biotechnology was highlighted for its potential to transform disease prevention, diagnosis, and treatment, thereby improving patient outcomes and reducing healthcare costs. It was also recognized for advancements in regenerative medicine and organ transplantation.

Fifteen respondents focused on biotechnology's positive environmental impacts. They mentioned bioremediation techniques, bio-based renewable energy sources, and sustainable industrial processes as means to reduce pollution and greenhouse gas emissions. Biotechnology was seen as pivotal for biodiversity conservation, ecosystem restoration, and climate change mitigation, offering solutions to environmental challenges like pollution control and waste management. Fifteen responders highlighted biotechnology's significant economic potential. They emphasized its role in fostering innovation, entrepreneurship, and job creation across biopharmaceuticals, biomanufacturing, and agriculture sectors. Biotechnology was noted for attracting investments, driving economic growth, and enhancing Malaysia's global competitiveness in biotech markets. Collaboration among academia, industry, and government was stressed for maximizing biotechnology's economic benefits and technology transfer. Nine respondents underscored the importance of education and research in advancing biotechnology. They emphasized investing in STEM education, vocational training, and lifelong learning to cultivate a skilled workforce capable of driving biotech innovation. Strong research infrastructure, funding support, and interdisciplinary collaboration were deemed crucial for accelerating scientific discoveries and technology transfer. Ethical considerations and fostering a culture of responsible innovation were also highlighted.

Improving public understanding of biotechnology requires a multifaceted approach involving education, communication, and collaboration. Fig. 7 illustrates a diverse range of suggestions from respondents on how to effectively enhance biotechnology awareness across Malaysia. These include the implementation of workshops, school-based programs, and specialized training; the use of traditional and digital media for broader outreach; and the formation of partnerships between educational institutions, industries, and government agencies. Respondents also proposed creative strategies such as competitions, policy advocacy, and the use of digital influencers to better engage the public, particularly younger audiences. These suggestions reflect a strong public interest in making biotechnology more accessible, engaging, and impactful at all levels of society.

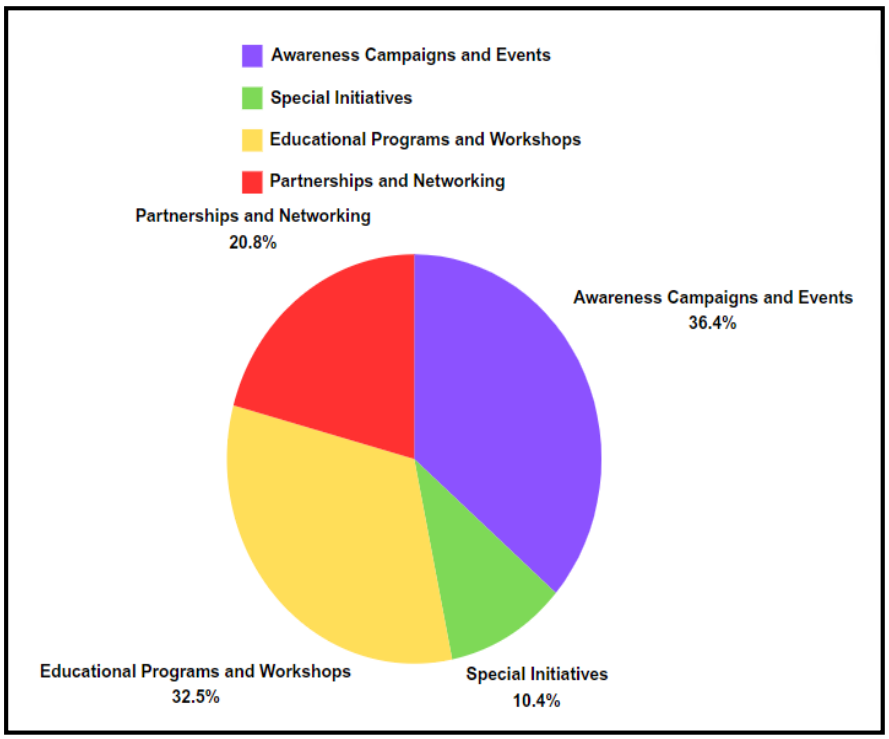

Fig. 7 Suggestions on in enhancing public understanding of biotechnology in Malaysia

Twenty-five respondents emphasized the pivotal role of educational programs and workshops in enhancing public understanding of biotechnology. Among them, eight highlighted the importance of organizing workshops, seminars, and community programs to provide platforms for expert insights and engaging discussions tailored to

diverse groups. Six respondents stressed the need for specialized courses or training programs to equip specific communities or businesses with biotechnology-related skills. Additionally, eleven respondents advocated for introducing biotechnology programs in schools, including hands-on activities and extracurricular events, to stimulate early engagement and foster curiosity among students. Twenty-eight respondents underscored the necessity of raising biotechnology awareness among the general population. Ten respondents supported traditional media efforts such as television, radio, and newspapers to disseminate information broadly about biotechnology's benefits and drawbacks. Eight respondents emphasized the significance of community events like exhibitions, fairs, and public lectures as avenues for community engagement and hands-on learning opportunities. Additionally, ten respondents highlighted the importance of digital outreach through social media platforms, websites, and online forums to engage online audiences effectively with engaging content such as videos, infographics, and blogs.

Sixteen respondents highlighted the critical role of partnerships in enhancing public involvement with biotechnology. Four respondents emphasized the importance of industrial partnerships to facilitate collaborative research, resource sharing, and knowledge transfer between academia and industry. Eight respondents advocated for school-university partnerships to enhance biotechnology education and awareness in schools by providing resources, expertise, and mentorship. Additionally, four respondents stressed the need for agency networking to establish collaborations with government agencies, non-profits, and community groups to align efforts and maximize impact in biotechnology education and outreach. Eight respondents emphasized the importance of innovative approaches to engage diverse audiences in biotechnology awareness programs. Three respondents advocated for novel initiatives such as challenges, competitions, and themed events to generate interest and participation. Two respondents highlighted the significance of policy advocacy to promote biotechnology integration into national policies and education curricula. Furthermore, three respondents emphasized the potential of digital platforms like Instagram, TikTok, and YouTube to reach younger audiences effectively and promote biotechnology through viral content, live streams, and influencer collaborations.

5. Conclusion

In conclusion, this study has provided a nuanced understanding of public perceptions towards biotechnology in Malaysia, particularly in relation to the National Biotechnology Policy (NBP) 2.0. Our findings reveal a spectrum of opinions among Malaysians regarding their awareness and perspectives on biotechnological advancements aimed at fostering a bioinnovative society. While some respondents exhibited strong support for the NBP 2.0, acknowledging its potential to revolutionize sectors such as agriculture and healthcare, others expressed scepticism or unfamiliarity. This diversity underscores the need for targeted educational initiatives and awareness campaigns to bridge knowledge gaps and foster informed public discourse on biotechnological policies and their implications. Moreover, the study highlights significant implications for advancing Malaysia's biotechnology sector. The varying degrees of familiarity and endorsement of NBP 2.0 suggest opportunities for enhancing engagement and collaboration between the government, research institutions, and the public. By addressing concerns and increasing transparency, Malaysia can cultivate an environment conducive to biotechnological innovation, bolstering its position in the global biotech landscape. Furthermore, the insights underscore the importance of adaptive policy frameworks that not only address current societal needs but also anticipate future challenges in biotechnology governance and regulation.

Lastly, the study emphasizes the importance of continuous dialogue and community engagement in shaping the trajectory of biotechnology adoption in Malaysia. Beyond policy implementation, fostering a culture of inclusivity and ethical considerations in biotechnological research and development is crucial. Public trust, garnered through transparent communication and meaningful public participation, will be pivotal in navigating the ethical, social, and environmental dimensions of biotechnological advancements. Moving forward, initiatives that promote dialogue, education, and collaboration will be essential in harnessing the full potential of biotechnology to address global challenges and improve societal well-being. This conclusion encapsulates the study's key findings, implications, and recommendations, focusing on the pivotal role of public awareness and engagement in shaping biotechnological policies and practices in Malaysia.

Acknowledgement

The project was funded under Geran Sumbangan Suruhanjaya Kebangsaan UNESCO Malaysia (SKUM) 2023 (Project Vot No. X275), Ministry of Tourism, Arts & Culture, and Ministry of Higher Education. The authors also expressed sincere appreciation to the Department of Food Science and Technology, Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia, Pagoh, and Asian Federation of Biotechnology (AFOB) for supplying essential facilities and offering valuable assistance throughout the completion of this research.

Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Sareniya Sekaran, Siti Fatimah Zaharah Mohamad Fuzi;* ***data collection:*** *Sareniya Sekaran, Siti Fatimah Zaharah Mohamad Fuzi;* ***analysis and interpretation of results:*** *Sareniya Sekaran, Siti Fatimah Zaharah Mohamad Fuzi;* ***draft manuscript preparation:*** *Sareniya Sekaran, Siti Fatimah Zaharah Mohamad Fuzi, Suraini Abd Aziz, Phang Lai Yee, Madihah Salleh. All authors reviewed the results and approved the finals version of the manuscript. The author confirms sole responsibility for the following: study conception and design, data collection analysis and interpretation of results and manuscript preparation.*

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