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DEVELOPMENT OF NUTRACEUTICAL SPIRULINA-MORINGA OLEIFERA (NUTRISMO) PRODUCTS AS NATURAL IMMUNOMODULATOR AND ANTIOXIDANT SUPPLEMENTS

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ABSTRACT

Phycocyanin research shows fluctuating trends and remains underexplored, particularly in its application for functional food and nutraceutical development, creating significant research gaps and opportunities for innovation such as NutrisMO This study aims to identify research trends and gaps in phycocyanin studies and to analyze factors influencing consumer intention to use NutrisMO, a nutraceutical product based on Spirulina and Moringa oleifera.A Systematic Literature Review (SLR) was conducted using the PRISMA approach with data sourced from Scopus (2005–2024), analyzed באמצעות VOSviewer and Leximancer. In addition, a quantitative explanatory study was conducted with 150 respondents selected through purposive sampling to review public acceptance of NUTRISMO products. Data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with Smart-PLS. The SLR results indicate that research on phycocyanin is still limited and fluctuative, with identified gaps in food-related applications (21%), product-related challenges (8%), and C-phycocyanin concepts (6%), highlighting opportunities for further research and innovation. Meanwhile, the Smart-PLS analysis shows that all constructs meet validity and reliability criteria. Perceived Bioactive Content (β = 0.400), Health Awareness (β = 0.438), and Trust in Herbal Products (β = 0.440) significantly influence Perceived Benefit, which in turn strongly affects Intention to Use (β = 0.775). The model demonstrates moderate to strong explanatory power, with R^2 values of 0.513 for Perceived Benefit and 0.600 for Intention to Use. This study confirms that perceived benefit plays a crucial mediating role in shaping consumer intention to use nutraceutical products. It also emphasizes the need for further research on phycocyanin and supports the development of functional nutraceutical innovations like NutrisMO by integrating scientific evidence, health awareness, and consumer trust.

Keywords: immunomodulator; moringa oleifera; natural antioxidant; nutrisMO; spirulina

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INTRODUCTION

Microalgae are beneficial to human health in a number of areas, including biofertilizers, food, feed, cosmetics, and medicine. Cyanobacteria, sometimes referred to as blue-green algae, are a class of photosynthetic organisms that fall within the bacterial domain. Cyanobacteria are a kind of bacteria that go by the name "algae" but are not truly algae. Because they can photosynthesize and provide oxygen, cyanobacteria are vital to the ecology. Cyanobacteria is a Gram-negative phylum that gets its energy from photosynthesis (Abalde et al., 1998; Kao et al., 1973; Streit et al., 2017). Because of their prokaryotic cell structure, cyanobacteria lack a membrane-separated cell nucleus. Cyanobacteria may survive in a variety of environments, including freshwater, saltwater, soil, and harsh environments like volcanic ash. The cyanobacteria category includes gloeocapsa, nostoc, synechococcus, anabaena, microcystic, and spirulina, among other forms and environments (Fadel et al., 2014; Paramanya et al., 2024).

Spirulina, a spiral-shaped microalgae, is one of the best microalgae available right now. Because of its great nutritional value, spirulina is used as a dietary supplement. Spirulina is a rich source of minerals, vitamins, lipids, proteins, pigments, and antioxidants. A number of other substances are also present, including iron, vitamin B12, amino acids, ficoerythrin, and Phycocyanin. A functional diet may be made from spirulina due to its nutritional content and various qualities. Its protein concentration ranges from 55-70%, while important amino acids (1.3-15%), vitamins, and minerals (3%-7%), chlorophyll (0.8%), and ficocyanis (6.7-11.7%) are also present (Pan-Utai et al., 2022; Sivaramakrishnan et al., 2022; Soliman et al., 2024). Spirulina cells are spiral or helical in shape and typically measure 0.5–1 micrometers in diameter and 1-2 micrometers in length. Ficoerythrin and Phycocyanin, two pigments involved in photosynthetic processes, give spirulina its characteristic blue-green hue. Spirulina is a marine algae that grows in both fresh and saltwater, both warm and cold. Spirulina can survive in tropical and subtropical seas with high pH levels (between 8 and 11) and ideal temperatures between 25 and 35 degrees Celsius (Kargın & Dikbaş, 2020).

According to Solanki et al. (2023), spirulina is a multicellular blue-green microalgae (prokaryote) that is high in nutrients such as protein, vitamins and minerals. The nutrients in spirulina are higher than other foods such as soybeans. In addition, spirulina is also known as antiviral, antibacterial, anticancer, anti-inflammatory, antidiabetic, can also be used as a toxic mineral detoxifier and can stimulate the immune system. According to Ahmad et al. (2022), Spirulina has anti-anemia, anti-genotoxic, anti-nefrotoxic, anti-obesity activities, is beneficial for eye health and is neuroprotective. Spirulina is often referred to as super food which has high economic value so that many people are interested in cultivating spirulina.

Millions of spirulina consumers worldwide are farmed spirulina cultivators. Presently, 68,025 tons of spirulina are predicted to be produced annually for human use worldwide in 2025, up from over 10,000 tons in 2021. With 80% of the global spirulina output, China leads the world in spirulina production, followed by the US, Taiwan, Thailand, and India (Adli et al., 2020; Bhatt et al., 2020; Cherdkiatikul & Suwanwong, 2014). Indonesia have the potential to generate spirulina due to its favorable geographic location. Phycocyanin, an oxygenic pigment with a blue hue found in fikbilisomes, has a wide range of uses in the food, pharmaceutical, biotechnological, and industrial sectors (Su et al., 2023). As a tetrapirole ring processing phycobilin, phycocyanin is a member of the chromophoric protein family (Hu et al., 2024; Killilea et al., 1980; Pez Jaeschke et al., 2021; X. Zhang et al., 2021). Electron microscopy study showed that the phycocyanin arrangement is on the surface of thylakoids (Cao et al., 2022). More than 20% of Spirulina platensis's dry weight is made up of phytocyanin (Jia et al., 2014; F. Yang et al., 2014).

A wide range of monomers, trimers, hexamers, and other oligomers make up Phycocyanin. Phycocyanin belongs to the phycobiliprotein group, which also consists of two additional proteins: allo Phycocyanin (blue) and phycoerythrin (red) (T. Jiang et al., 2001; Kronfel et al., 2013; Rahman et al., 2017). Phycocyanin is a natural product in spirulina, accounting for 20–25% of its total biomass (Horváth et al., 2013; Hotos, 2021). The open tetrapiol chromophore phycocyanobilin, which is covalently attached to apoproteins (Liu et al., 2023; Rockwell et al., 2017) is responsible for the deep blue hue of phycocyanin. The pigment structure is made up of heterodimers, which are complex super molecular proteins made up of α (alpha) and β (beta) subunits with molecular weights of 18 and 20 kDa, respectively (Prates et al., 2018; R. Silva et al., 2024). The main objective of this study is to assess the development potential of spirulina in Indonesia using a meta-analysis. We want to learn more about the application of phycocyanin, which is found in spirulina, to several technological advancements in the domains of cosmetics, medicine, and functional foods through this meta-analysis.

Global public health currently faces serious challenges in the form of the increasing prevalence of degenerative diseases, a weakened immune system due to modern lifestyles, and exposure to oxidative stress that contributes to various metabolic disorders (Abdelnour et al., 2020; Seyedalangi et al., 2024). These conditions make people more susceptible to infections and increase the risk of chronic diseases such as diabetes, cardiovascular disease, and cancer (Li, 2022; Pan-utai & Iamtham, 2019). One effective preventive strategy is to provide nutraceutical products based on natural ingredients that can function as both immunomodulators and antioxidants. In this context, Spirulina (Arthrospira platensis) and Moringa oleifera are highly potential candidates. Spirulina is a microalgae rich in protein, essential amino acids, vitamin B12, bioactive pigments such as phycocyanin (Bertolin et al., 2011; Gámez-Ortiz et al., 2019), and essential minerals, which have been shown to have antioxidant and anti-inflammatory activities, as well as enhancing immune responses (Bonos et al., 2016; Puglisi et al., 2022; Tao et al., 2022). Meanwhile, Moringa oleifera contains bioactive compounds such as flavonoids, phenolics, vitamin C, β-carotene, and minerals that support immune function and combat oxidative stress (Alvionita et al., 2022; Noris, 2024; Putu Ayu Sri Devi et al., 2023; M. G. D. Silva et al., 2022). The combination of these two ingredients is believed to provide a stronger synergistic effect in supporting health. However, research examining the formulation, characterization, and scientific evidence of the Spirulina-Moringa combination is still very limited. To date, studies have focused more on the effects of both ingredients separately.

The main problem formulated in this research is how to produce an optimal formulation of Spirulina-Moringa oleifera (NutrisMO) as a nutraceutical product, what the chemical, physical, and bioactive characteristics of the resulting product are, and how the immunomodulatory and antioxidant activities of NutrisMO can be demonstrated analytically and experimentally. Therefore, this research aims to develop an optimal formulation of Spirulina-Moringa oleifera (NutrisMO) as a nutraceutical product.

METHOD

Systematic Literature Review (SLR)

This kind of study is a meta-analysis that makes use of Vosviewer and Leximancer for the literature evaluation process (Sutriawan et al., 2024). Leximancer is used to identify research gaps and to understand the notion of research difficulties, whereas Vosviewer is used to observe the whole network generated about physicocyanin. The Scopus database was consulted for data sources, and relevant publications were found by searching for the term "physicocyanin." A set of inclusion and exclusion criteria was established in order to gather pertinent materials. The following is the study range's inclusion and exclusion criteria for 2005–2024, with the term “phycocyanin” appearing in the title, abstract, and keywords. The prism approach, which was derived from (Donthu et al., 2021) is the research methodology used in the systematic literature review study (see Figure 1).

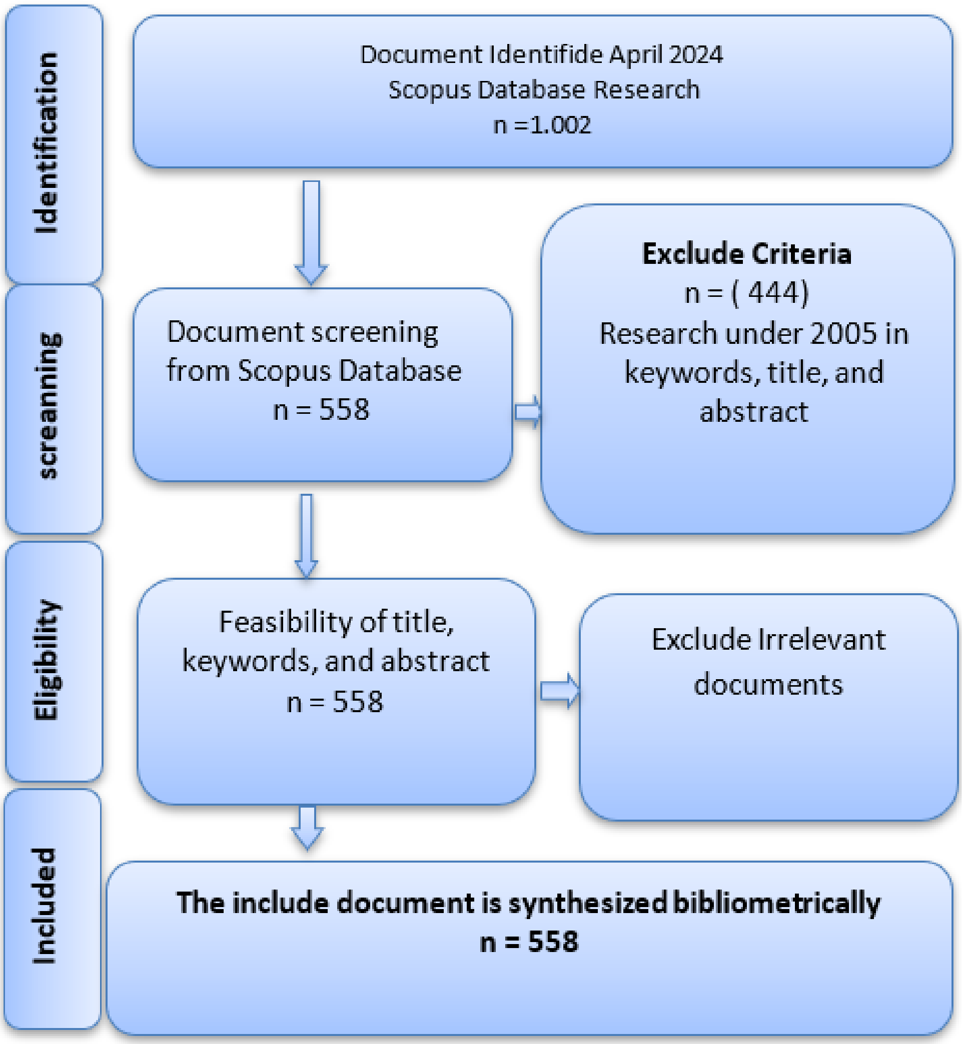


Figure 1. Procedures Research PRISMA (Donthu et al., 2021).

NutrisMO Product Development

Meanwhile, developing functional-based food innovations for nutraceutical items entails creating tools and resources, developing products, and disseminating them. This study used a quantitative method with an explanatory design to investigate the links between factors that influence the desire to take the nutraceutical product NutrisMO. The Partial Least Squares Structural Equation Modeling (Smart-PLS) approach was used to analyze data, employing Smart-PLS software as a tool. The PLS-SEM technique was chosen because it can assess complicated models with latent variables and does not require a precise normal distribution of data.

The study focused on individuals considered potential consumers of nutraceutical products, involving 150 respondents selected through purposive sampling. Data was collected using a five-point Likert-scale questionnaire assessing agreement levels. The research model included five latent constructs: Perception of Bioactive Content, Health Awareness, Trust in Herbal Products, Perception of Benefits, and Intention to Use, each measured with three indicators. The measurement model's validity was evaluated through convergent validity and reliability tests, confirming all indicators met the threshold with loadings above 0.70. A structural model analysis evaluated relationships using path coefficients and R^2 values, while mediation analysis explored the role of Perceived Benefit in the relationships among variables. The study employed bootstrapping for significance testing, offering insights into the factors influencing the intention to consume Spirulina and Moringa oleifera-based nutraceutical products, highlighting perceived benefit's mediating role.

RESULT

Systematic Literature Review (SLR)

The systematic literature review's findings indicate that there would be a high need for phycocyanin-related research from 2005 to 2024. This is seen in Figure 1.

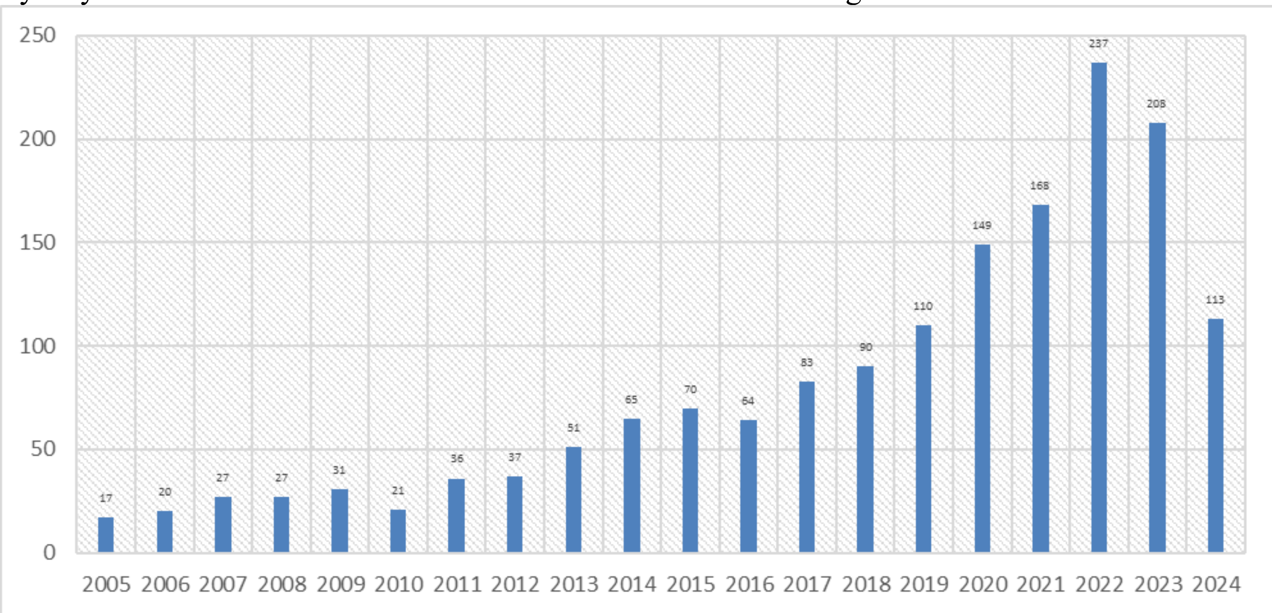
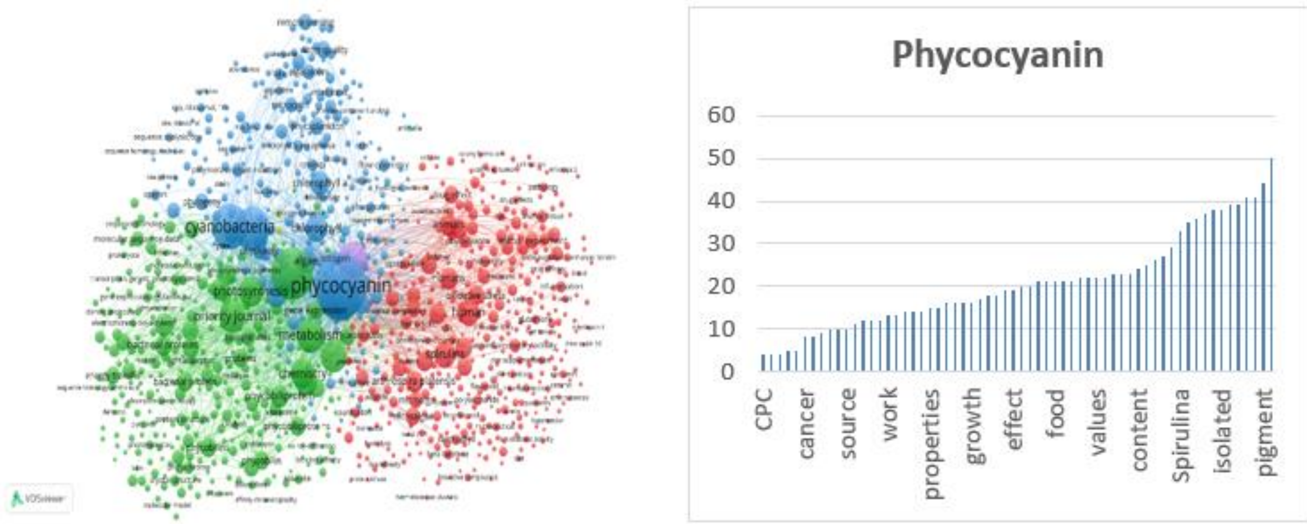
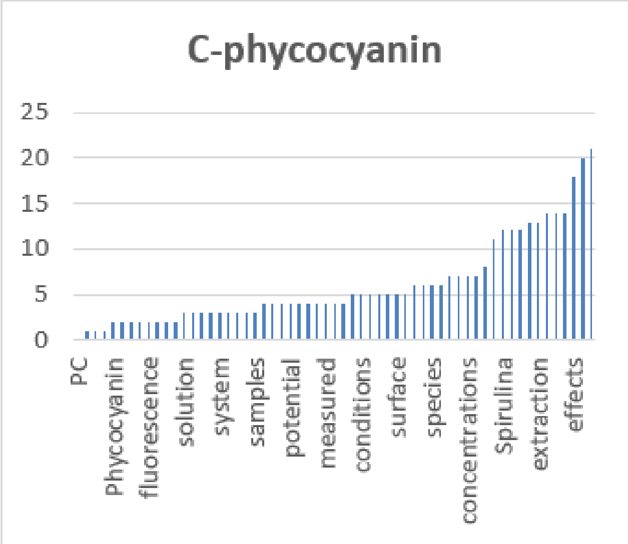


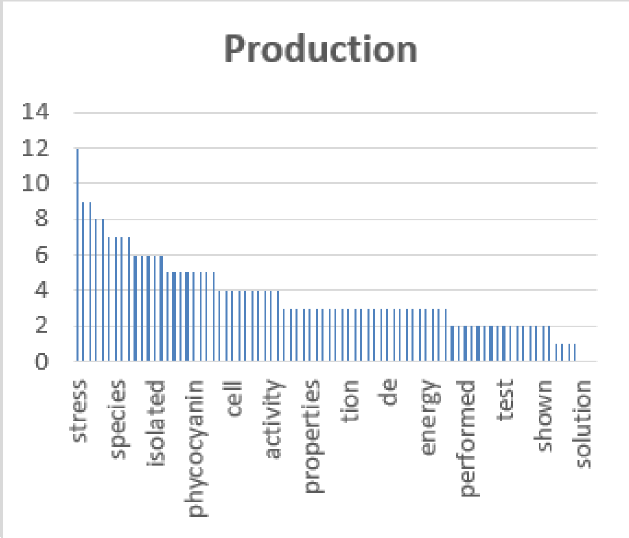
Figure 2 Phycocyanin Research Distribution from 2005-2024

The analysis's findings indicate that, while the frequency of studies on phycosianin ranged from 237 to 2022, the distribution of such studies is erratic. While there was a decline in research in 2023 and 2024. On the basis of this, there is a lot of room for further study on pahycosianin. Figure 2 displays the findings from the examination of concept difficulties and associated research gaps with phycosianin.



(a) (b)





(c) (d)

Figure 3. (a) All Psyhcosianin Keywords; (b) psyhcosianin concept; (c) C-Phycocyanin concept; (d) Phycocyanin Production

There isn't much research on the term "phycocyanin," which creates a research gap or potential for more study. The percentage point for spirulina is 32%, and the findings of the examination of phycocyanin research concepts that center on food are about 21%. Research issues with phycocyanin products vary from 8%, whereas issues with the C-phycocyanin idea range from 6%. This is the basis of the study's gap, which is that the idea of psychocyanin production and usage is still difficult from a research viewpoint. This is displayed in Table 1.

Table 1.
The application of phycocyanin in cosmetics, medicine, and functional foods.

Field	Benefits	References
Functional food	Gives color to food or drink	(Carmona et al., 2022; García et al., 2021; Ghosh et al., 2024; Heddam et al., 2019; Ma et al., 2023; Song et al., 2012)
	Protect food and add to its physicochemical and bioactive functions	(García et al., 2021; Hentati et al., 2020; Li et al., 2022; Sotiroudis & Sotiroudis, 2013; Wan et al., 2021)
	Additional food source in sauces, soups, noodles, bread and biscuits	(Su et al., 2023).
	Additional source in Ice cream	(Boyanova et al., 2022; Bürck et al., 2024; Campos Assumpção de Amarante et al., 2020; Safari et al., 2022; Sun et al., 2022)
	A mixture for making bread with high nutritional content	(Abdulagatov et al., 2018; Lemos et al., 2020; Wang et al., 2012)
Medicine	Pharmaceutical for liver cancer	(Bingula et al., 2016; Fujihara et al., 2021; L. Jiang et al., 2017; Khan et al., 2005; Ou et al., 2023; Wei & Guo, 2022; Wollina et al., 2018; F. Zhang et al., 2015)
	Pharmaceutical for Breast cancer	(Baudelet et al., 2013; Bharathiraja et al., 2016; Dimarti et al., 2020; Heisnam et al., 2022; L. Jiang et al., 2018a, 2018b; Ouhtit et al., 2014; Ravi et al., 2015; Rizeq et al., 2020; Saad et al., 2024)
	Pharmaceutical for colon cancer	(Kaźmierczak-Siedlecka et al., 2023; Kefayat et al., 2019; Minic et al., 2016; Putri et al., 2020; Y. Yang et al., 2021; Y. Zhang et al., 2022)
	Pharmaceutical for Leukemia	(Carbone et al., 2021; Cuffaro et al., 2023; ElFar et al., 2022; Flores Hernandez et al., 2017; Geh et al., 2015)
	Pharmaceutical for lung cancer	(Hao et al., 2022; Hao, Li, Wang, Yan, et al., 2019; Hao, Li, Wang, Zhao, et al., 2019; Herbert et al., 2024; Ji et al., 2020; Saadaoui et al., 2020; Xin et al., 2023)

	irritable bowel syndrome (IBS) or inflammatory bowel disease (IBD)	(Zizzo et al., 2020)
	reduce injury to the lungs	(L. Zhang et al., 2022)
	preventing fibrosis through the expression of vimentin and fibronectin	(Jensen et al., 2015; Salama et al., 2021)
	Suppresses liver microsomal lipid peroxidation, foot inflammation, and edema caused by glucose oxidase	(D. Park et al., 2023; Schwarzkopf et al., 2014; Sokary et al., 2024; Stepanov et al., 2021)
	Promotes the demyelination process in damaged brain tissue caused by ischemic stroke	(Marín-Prida et al., 2012; Pentón-Rol et al., 2018a, 2018b, 2021)
	Nutraceutical for anti-diabetic	(Kaur et al., 2023; Lim et al., 2020; Munawaroh et al., 2023; Shaman et al., 2024; Tamel Selvan et al., 2023; Y. Zhang et al., 2022; Zidane et al., 2022)
Cosmetics	Bright and abundant natural dyes	(Gamal et al., 2023; Rahman et al., 2020; Walter et al., 2011; Yoshikawa & Belay, 2008)
	Active ingredients of hair dye	(Kraseasintra et al., 2022)
	Anti-acne properties indicate activity against the bacteria that cause acne.	(Kraseasintra et al., 2022; Nihal et al., 2018)
	reduces skin hyperpigmentation and protects skin from sun damage	(Favas et al., 2022; Kalasariya et al., 2023; Wu et al., 2011)
	anti-aging that protects cells from oxidative stress and free radical damage	(Farooq et al., 2014)

Neutraceutical Spirulina-Moringa Oleifera (NutrisMO)

The following are nutraceutical products based on Spirulina-Moringa Oleifera (NutrisMO), namely:

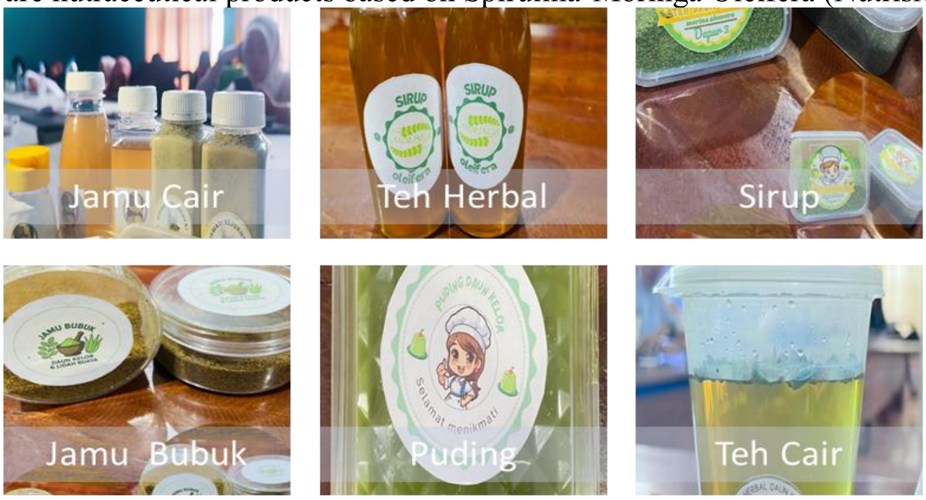


Figure 4. Neutraceutical Products Spirulina-Moringa Oleifera (NutrisMo)

The nutritional products developed consist of various products including liquid herbal medicine, herbal tea, syrup, powdered herbal medicine, pudding and liquid tea which are easy for patients to consume. Meanwhile, validity and reliability can be seen in the table below, namely as follows:

Tabel 2.
Construct Reliability and Validity

NutrisMO Product	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Health Awareness	0.899	0.903	0.937	0.832
Intention to Use	0.818	0.823	0.891	0.732
Perceived Benefit	0.773	0.773	0.869	0.688
Perceived Bioactive Content	0.900	0.909	0.937	0.833
Trust in Herbal Products	0.893	0.903	0.933	0.824

All constructs in the NutrisMO product demonstrate strong validity and reliability, with Cronbach's

Alpha values ranging from 0.773 to 0.900, indicating high internal consistency. Rho_A values (0.773–0.909) and Composite Reliability (0.869–0.937) also surpass the 0.7 threshold, confirming composite reliability. Additionally, Average Variance Extracted (AVE) values between 0.688 and 0.833 exceed the minimum of 0.5, reflecting good convergent validity. The variables Health Awareness, Intention to Use, Perceived Benefits, Perceived Bioactive Content, and Trust in Herbal Products satisfy the criteria for an effective measurement model, qualifying them for further structural analysis.

Tabel 3.
R-Square

	R Square	R Square Adjusted
Intention to Use	0.600	0.597
Perceived Benefit	0.513	0.503

The R Square values in the model indicate a strong explanatory ability for the endogenous variables. The Intention to Use construct has an R Square of 0.600 (Adjusted 0.597), explaining about 60% of the variation in usage intention. Perceived Benefit has an R Square of 0.513 (Adjusted 0.503), explaining approximately 51.3% of the variance. Both values fall into the moderate to strong category, suggesting that the structural model possesses good predictive power and is relevant for explaining variable relationships in the NutrisMO research context. The measurement model assessment demonstrates that all constructs exhibit strong convergent validity and reliability. All indicator loadings for Perceived Bioactive Content, Health Awareness, Trust in Herbal Products, Perceived Benefit, and Intention to Use exceed the recommended threshold of 0.70, indicating that the indicators adequately represent their respective latent constructs. This suggests that the measurement model is robust and suitable for further structural analysis.

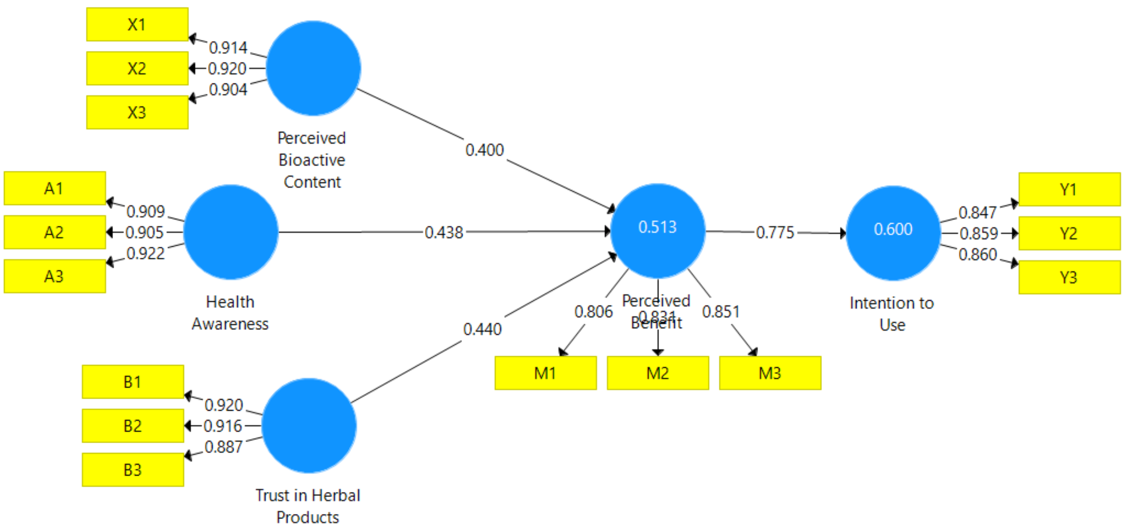


Figure 5. Results of the Perception Analysis of NutrisMo Development

The structural model results reveal that Perceived Bioactive Content (β = 0.400), Health Awareness (β = 0.438), and Trust in Herbal Products (β = 0.440) all have positive and moderate effects on Perceived Benefit. Among these, Trust in Herbal Products shows the strongest influence, although the effects of all three predictors are relatively comparable, indicating that consumer perceptions of nutraceutical products are shaped by a combination of scientific understanding, personal health consciousness, and confidence in herbal remedies. The coefficient of determination ($R^2 = 0.513$) indicates that 51.3% of the variance in Perceived Benefit is explained by these three exogenous variables, reflecting a moderate explanatory power. See figure 5.

Furthermore, Perceived Benefit has a strong positive effect on Intention to Use (β = 0.775), suggesting that individuals who perceive higher benefits from the NutrisMO nutraceutical are significantly more likely to adopt and consume the product. The R^2 value of 0.600 indicates that 60% of the variance in Intention to Use is explained by Perceived Benefit, demonstrating substantial predictive relevance. These findings confirm the mediating role of Perceived Benefit, indicating that the influence of Perceived Bioactive Content, Health Awareness, and Trust in Herbal Products on consumption intention operates indirectly through the formation of perceived benefits. Overall, the model provides empirical support for the theoretical framework linking nutraceutical perception and consumer behavior. It highlights the central role of perceived benefits as a key determinant of consumption intention, while also emphasizing the importance of enhancing consumer awareness, trust, and understanding of bioactive components in promoting the acceptance of nutraceutical products such as NutrisMO.

DISCUSSION

Food coloring, for example, is a dye that adds color to food or beverages. Research on phytocyanin products has shown this (Buecker et al., 2024; García et al., 2021; Minchev et al., 2021; Zhou et al., 2023). While synthetic dyes are more stable and simpler to get than natural colors, they can lead to a number of illnesses and conditions, including genotoxicity, hypersensitivity, and carcinogenic consequences. Thus, substitute coloring agents are being searched for that not only provide color to food but also safeguard it and provide physicochemical and biological properties (Malwade et al., 2016; Novokshanova et al., 2023). Natural food coloring is derived from a variety of sources, including microbes, plants, and animals. The lack of year-round availability, high product costs, and lack of scalability of dyes made from plants and animals limit their use (García et al., 2021; Sidor et al., 2023; Sun et al., 2023). An other natural food coloring source that is easy to create, inexpensive to produce, and year-round is microorganisms, particularly microalgae (Sidor et al., 2023). A kind of microalgae known as spirulina uses phycocyanin, which has an incredibly appealing blue color, to replace food coloring (García et al., 2021)

The results of color research on phycocyanin incorporated in three types of beverages, such as wine, isotonic drinks and tonics showed its stability as a substitute for synthetics (García et al., 2021). Phycocyanin was experimentally incorporated into food and beverage products. Phycocyanin was incorporated into ice cream with studied antioxidant activity 13-fold higher than the control (Singh & Sherman, 2006). Formulated skim milk enriched with phycocyanin for high efficacy and antioxidant properties (Galetovic et al., 2020). Dried spirulina can be used as an additional food source in sauces, soups, noodles, bread, and biscuits (Su et al., 2023). Phycocyanin powder is used as a fortification ingredient in pasteurized fresh cow's milk yogurt (Perotti, 2013) and as a bread-making mix with high nutritional content increasing its application in the food industry (Bai et al., 2023; Rojas-Franco et al., 2021).

Phycocyanins have been used to treat cancer naturally because they have anti-cancer properties against various types of cancer, such as liver cancer (Bingula et al., 2016; Fujihara et al., 2021; L. Jiang et al., 2017; Khan et al., 2005; Ou et al., 2023; Wei & Guo, 2022; Wollina et al., 2018; F. Zhang et al., 2015), breast cancer (Baudelet et al., 2013; Bharathiraja et al., 2016; Dimarti et al., 2020; Heisnam et al., 2022; L. Jiang et al., 2018a, 2018b; Ouhtit et al., 2014; Ravi et al., 2015; Rizeq et al., 2020; Saad et al., 2024), colon cancer (Kaźmierczak-Siedlecka et al., 2023; Kefayat et al., 2019; Minic et al., 2016; Putri et al., 2020; Y. Yang et al., 2021; Y. Zhang et al., 2022), leukemia (Carbone et al., 2021; Cuffaro et al., 2023; ElFar et al., 2022; Flores Hernandez et al., 2017; Geh et al., 2015), lung cancer (Hao et al., 2022; Hao, Li, Wang, Yan, et al., 2019; Hao, Li, Wang, Zhao, et al., 2019; Herbert et al., 2024; Ji et al., 2020; Saadaoui et al., 2020; Xin et al., 2023). The mechanism allows phyocyanin to have anticancer activity by suppressing the cell cycle at a certain phase, modifying the redox state of the cell, and increasing the expression of various genes and receptors that play a role in necrosis and apoptosis (Shanmugam et al., 2017) . The antimicrobial ability of phycocyanin can reduce the growth of pathogenic bacteria such as Eschericia soli, Bacillus, Staphylococcus aerus, Salmonella thypi (Shanmugam et al., 2017). Listeria monocytogenes, Yersinia ruckeri, Streptococcus iniae (Shanmugam et al., 2017), Aeromonas hydrophilia, Enterococcus faecalis (Khazi et al., 2021). The antibacterial activity of phycocyanin can fight Pseudomonas aeruginosa, Klebsiella pneumoniae (Choksi et al., 2020) and inhibit the growth of fungi Candida albicans, Aspergilllus niger, A. flavous, Penicillium sp., Rhizopus sp. (Kraseasintra et al., 2022).

Exploration of the cosmetics industry is also developing phycocyanin as a bright and abundant natural colorant. Lip balms from phycocyanine have been produced by various companies reaching many customers (Minchev et al., 2021). Phycocyanin also has potential as an active ingredient for hair dye because after 5 shampoo washes 50% of the hair color remains intact. Apart from being a colorant, Phycocyanin can be formulated for anti-aging creams because it is an antioxidant that eliminates reactive oxygen species (ROS) as the main cause of aging (Shanmugam et al., 2017)

The results of Xu et al. (2022) using phycocyanin reported that the anti-melanogenic properties of phycocyanin can suppress melanin synthesis which could have potential use in the form of sunscreens. Anti-acne properties of phycocyanin have been revealed to show activity against acne-causing bacteria, namely Propionibacterium acne and Staphylococcus epidermidis (Kraseasintra et al., 2022; Nihal et al., 2018). The presence of C-phycocyanin (C-PC) content in Spirulina makes it a good photoprotective source (W. S. Park et al., 2018). Phycocyanin can reduce skin hyperpigmentation and protect the skin from sun damage by inhibiting dermis damage. Phycocyanin can function as a moisturizer in facial creams because it hydrates the skin's strongest layer and controls excess oil in the skin tissue (Zhou et al., 2023). The antioxidant content in Phycocyanin is utilized as an anti-aging mask that protects cells from oxidative stress and free radical damage (Seo et al., 2013).

CONCLUSION

The study integrates findings from a systematic literature review and Smart-PLS analysis into a comprehensive framework. The literature review indicates that research on phycocyanin from 2005–2024 is limited and variable, highlighting gaps in food applications and C-phycocyanin concepts, which present opportunities for nutraceutical innovation. The Smart-PLS analysis confirms strong model validity, reliability, and predictive power, showing that Perceived Bioactive Content, Health Awareness, and Trust in Herbal Products positively influence Perceived Benefit, which mediates the intention to use NutrisMO products. This underscores the importance of perceived benefit in adopting Spirulina and Moringa oleifera-based nutraceuticals.

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