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Review Article

Modification of *Zingiber officinale* capsules using solid dosage form technology as an adaptogen to accelerate the entry of local herbs into the global market: A review

Ovalina SB. Ginting[1]*, Salwa S. Fathaniah[1], Nabila HB. Barus[1], Sari FN. Sihite[1], Noela CV. Bintang[1], Cahyu M. Nainggolan[1], Miranda GB. Surbakti[1] and Kezya R. Sinabariba[1]

[1]Department of Pharmaceutical Technology, Faculty of Pharmacy, Universitas Sumatera Utara, Medan, Indonesia

*Correspondence: ovalina@usu.ac.id

Abstract

Ginger (*Zingiber officinale*) is a widely used medicinal plant with reported antioxidant, anti-inflammatory, antidiabetic, and immunomodulatory properties, supporting its potential development as a local adaptogenic herbal product. However, the development of ginger-based products in Indonesia remains largely limited to local use and conventional preparations. At the same time, international market entry requires improved formulation quality, product stability, bioavailability, standardization, and stronger scientific documentation. Literature searches were conducted in PubMed, Google Scholar, and Portal Garuda databases for original research articles published in English or Indonesian between 2019 and 2026, yielding ten relevant studies. This review discusses the potential modification of ginger capsules using solid dosage form technology to support the development of local herbs as competitive adaptogenic products in the global market. This review also discusses the pharmacological potential of ginger as an adaptogen, the characteristics of ginger as an active ingredient, formulation approaches for ginger extract capsules, comparison of capsule quality parameters, factors affecting capsule quality, and the market opportunity of ginger compared with established global adaptogens such as ashwagandha. This review emphasizes the role of excipient selection, capsule formulation strategy, microencapsulation, dissolution performance, stability considerations, and product standardization in improving the quality and competitiveness of ginger-based solid dosage forms. Overall, the development of modified ginger capsules using appropriate solid dosage form technology may strengthen the position of Indonesian ginger as a promising local herbal product for future global market expansion.

Keywords: *Zingiber officinale,* modified capsule, adaptogen, global market, solid dosage form technology

Introduction

Ginger (*Zingiber officinale*) is an herbal plant that has been extensively studied and is now being developed into various modern dosage forms to enhance its therapeutic value [1]. Ginger is used not only in phytochemical and biological activity tests such as antioxidant activity but also in the development of solid dosage formulations to improve stability and ease of use [2]. Ginger rhizomes contain various active phytochemical compounds such as flavonoids, phenols, and gingerols that have potential as antioxidants, antimicrobials, and therapeutic agents, thereby

Received: May 15, 2026 - Accepted: July 25, 2026 - Published online: July 31, 2026

presenting opportunities for development as high-value natural ingredients in the health and pharmaceutical sectors, as well as for expansion into global markets [1]. Research on adaptogenic plants like ginger is also showing rapid growth, encompassing various scientific approaches from the exploration of bioactive compounds to innovations in formulation technology [3]. Therefore, the development of ginger-based herbal formulations aims to improve efficacy, stability, and ease of use.

Ginger, as a local adaptogenic plant, is as effective as global adaptogenic plants such as ginseng and ashwagandha [3]. Ginger's bioactive compounds, primarily gingerol, shogaol, zingerone, and flavonoids, produce a variety of pharmacological activities [3]. Ginger exhibits strong antioxidant effects through free radical scavenging and the enhancement of endogenous antioxidant enzymes, anti-inflammatory effects through the inhibition of cyclooxygenase and prostaglandins, and antidiabetic effects through increased insulin sensitivity and α-glucosidase inhibition [3,4]. With such a comprehensive bioactive and pharmacological profile, ginger may be regarded as a promising adaptogen from Indonesia capable of competing in the global market [4].

Although ginger has demonstrated considerable adaptogenic potential through its antioxidant, anti-inflammatory, antidiabetic, and immunomodulatory activities, the development of ginger-based pharmaceutical products remains limited, particularly in Indonesia, where most studies have focused on conventional preparations and preliminary evaluations [1,3,4]. Current research on ginger capsules has primarily emphasized basic pharmaceutical quality attributes, such as weight uniformity and disintegration time, while critical parameters required for modern herbal product development—including dissolution performance, long-term stability, bioactive marker standardization (e.g., gingerols and shogaols), and bioavailability assessment—remain insufficiently investigated [5]. These limitations restrict the scientific evidence supporting product quality, consistency, and therapeutic performance, thereby limiting the competitiveness of ginger formulations in the global herbal market, where standardized manufacturing, robust quality control, and reproducible efficacy are essential requirements [6].

To address these formulation and standardization gaps, this review aims to synthesize current evidence on the development of ginger capsules as a modern solid dosage form with potential application as a globally competitive adaptogenic product. Specifically, this review aims to analyze formulation technologies used in ginger capsule development, including extraction approaches, excipient selection, and capsule manufacturing processes; compare the quality attributes of ginger capsule formulations across studies, particularly physical characteristics, disintegration, dissolution, stability, and active compound release; and assess the potential of ginger as a competitive adaptogen based on its bioactive constituents, including gingerols, shogaols, and flavonoids, as well as its reported pharmacological activities. This review is expected to provide evidence-based recommendations for improving the formulation quality, standardization, and global competitiveness of Indonesian ginger capsule products.

Methods

The literature search was conducted using PubMed, Google Scholar, and Portal Garuda databases with the following keywords: "*Zingiber officinale* capsule," "ginger capsule formulation," "solid dosage ginger," and "herbal adaptogen capsule." The inclusion criteria comprised original research articles published between 2019 and 2026 in English or Indonesian. A summary of the search strategy is presented in **Table 1**.

Table 1. Literature search strategy

Aspect	Description
Databases	Google Scholar, PubMed, Portal Garuda
Keywords	"*Zingiber officinale* capsule," "ginger capsule formulation," "solid dosage ginger," "herbal adaptogen capsule"
Inclusion criteria	Original research articles published between 2019 and 2026 in English or Indonesian
Target literature	A minimum of 10 studies related to ginger capsule formulation

Characteristics of ginger as an active ingredient

Gingerol is the primary metabolite of ginger that exhibits pharmacological activity [7]. The main compounds responsible for the spicy flavor in red ginger are shogaol and gingerol, whereas gingerol is unstable at high temperatures and can be hydrolyzed into shogaol [5]. Both of these compounds are known to possess antihepatotoxic properties against carbon tetrachloride and galactosamine, which can cause liver damage in rats [6]. Additionally, the compounds 6-gingerol, 8-gingerol, and 10-gingerol have the potential to reduce cardiotonic activity, while 6-shogaol has an antitussive effect and is capable of reducing intestinal contractions [7,8].

Red ginger is more widely used as a raw material for medicine due to its higher content of oleoresin (3%) and essential oil (2.58–2.72%) compared to other types of ginger [7]. Oleoresin is an extract product containing active components with potential as antioxidants and antimicrobials [5]. However, a drawback of oleoresin is its susceptibility to environmental factors such as heat, light, and microorganisms, which can cause degradation of the active components [6]. Therefore, oleoresin can be protected from environmental influences through an encapsulation process [8].

The chemical composition of ginger is complex, containing about 169 chemical constituents. The chemical constituents include monoterpenes, sesquiterpenes, diterpenes, vanilloids, flavonoids, and others. The biological activities of ginger might be due to the synergistic or additive effects of these compounds [9]. In addition, ginger contains amino acids, vitamins, and trace elements (iron, copper, manganese, zinc, chromium, nickel, strontium, and others). The major bioactive compounds in red ginger are vanilloids containing a 3-methoxy-4-hydroxyphenyl (vanillyl) moiety [9].

Comparison of ginger extract capsule formulations

Five ginger capsule formulations employing different solid dosage form development approaches have been developed [5-7,10,11]. The formulations vary in terms of composition, intended therapeutic use, technological modifications, and evaluation parameters. A comparative summary of these formulations is presented in **Table 2**.

Table 2. Comparison of red ginger extract capsule formulations from various studies

Study	Objective and dosage form	Composition and evaluation	Advantages	Limitations
Oktadiana and Susanti (2022) [5]	Dysmenorrhea treatment; red ginger extract capsules	Red ginger extract (±43%), corn starch, Vivapur 101, Aerosil, talc, Mg stearate; weight 0.635 g; disintegration time: 2 min 12 s	Simple and stable formulation with rapid disintegration meeting pharmacopeial requirements	Evaluation limited to physical parameters; no dissolution or clinical studies
Idrus and Pa'ee (2021) [10]	Postnatal care; combined ginger-*Labisia pumila* capsules	Various ginger-*Labisia pumila* ratios (such as 1:1, 1:3); highest flavonoid at 1:3; highest antioxidant at 1:1; disintegration time: 15 min	Demonstrated anti-inflammatory and antioxidant benefits	Relatively long disintegration time; no single ratio optimized all parameters
Mahto *et al.* (2022) [11]	Polyherbal standardization; 8-plant capsule including ginger	Ginger 25 mg/500 mg (±5%) + other herbs; weight 533 mg; disintegration 3 min 25 s; 98.67% release at 30 min	Comprehensive standardization, high dissolution, acceptable microbiological quality	Complex formulation may limit reproducibility; no specific clinical evaluation
Christian and Suhardin (2025) [7]	Gingerol stability and bioavailability; transferosome-based microcapsules	Red ginger extract (3.9%), phosphatidylcholine-Span 80 system; spray-dried; size 261.8→433.7 nm; entrapment efficiency (EE) 77%→93.8%	Nanotechnology significantly improved stability and bioavailability	Complex and costly process; no in vivo studies reported

Study	Objective and dosage form	Composition and evaluation	Advantages	Limitations
Alburyhi and El-Shaibany (2025) [6]	Diabetes management; ginger extract capsules	Ginger extract (15%), diluent I (lactose, 45%), diluent II (microcrystalline cellulose, 39%), lubricant (1%); 96% release at 60 min (Formula 1, F1)	Excellent dissolution profile; promising for diabetes phytotherapy	No sustained-release developed; limited clinical evidence

Analysis of the optimal formulation

Based on the comparative data of ginger extract capsule formulations presented in **Table 2**, each study demonstrated distinct formulation characteristics, including differences in excipient composition, solid dosage form technology approaches, and evaluation parameters [5-7,10,11]. Therefore, the determination of the optimal formulation was conducted comprehensively by considering various quality indicators, including the physical characteristics of the dosage form, stability, dose uniformity, and the release profile of the active ingredient, all of which directly affect therapeutic efficacy [11].

The first formulation [5] represents a conventional capsule formulation approach utilizing standard excipients, such as corn starch, microcrystalline cellulose PH 101, talc, and magnesium stearate, which are widely applied in powder-filled capsule formulations. The primary advantages of this formulation include its simple composition and ease of manufacturing, making it highly feasible for large-scale production. In addition, the relatively rapid disintegration time indicates favorable disintegration properties and compliance with pharmacopeial standards. Nevertheless, the study exhibited certain limitations, particularly the absence of further evaluations, such as dissolution and stability assessments, thereby limiting the confirmation of the active compound's bioavailability [5].

In the second formulation [10], a combined herbal approach was employed by varying the ratio of ginger extract and *Labisia pumila*. This strategy provided added value through the potential synergistic pharmacological effects, particularly in terms of antioxidant and anti-inflammatory activities. The study demonstrated that variations in the ratio of active ingredients significantly influenced the flavonoid content and antioxidant activity of the formulation. However, the relatively prolonged capsule disintegration time indicated limitations in the release of active compounds. Furthermore, incorporating multiple active ingredients made it difficult to evaluate the specific contribution of ginger extract independently, thereby reducing the analytical focus on the effectiveness of a solely ginger-based formulation [10].

The third formulation [11] adopted a polyherbal approach containing 25 mg of ginger per 500 mg formulation (±5%), combined with several other herbal ingredients using the wet granulation method. This method is known to improve the flow properties and homogeneity of the powder mixture, thereby supporting capsule content uniformity. Furthermore, the dissolution test results demonstrated a high level of active compound release, indicating the potential for good bioavailability. The study was also supported by relatively comprehensive quality evaluations, including microbiological assessments. However, the complexity of the formulation involving multiple plant materials presents challenges in terms of standardization and reproducibility, particularly when the development is intended to focus on a single active ingredient-based formulation, namely ginger [11].

An advanced formulation approach was demonstrated in the fourth formulation [7] through the development of transferosome-based microcapsules combined with spray-drying technology. This formulation contained red ginger extract (3.9%) incorporated into a phosphatidylcholine-Span 80 transferosomal system and spray-dried using maltodextrin and gum Arabic as carrier agents. This technology has been shown to enhance the entrapment efficiency of active compounds while protecting against degradation caused by environmental factors. Consequently, the system exhibits significant potential to improve the stability and bioavailability of ginger's active constituents. Nevertheless, the complexity of the formulation process, the requirement for specialized materials, and the limited availability of in vivo and clinical evaluation data remain major challenges for the industrial-scale application of this technology [7].

Among all the analyzed formulations, the fifth formulation [6], containing ginger extract (15%), diluent I (45%), diluent II (39%), and lubricant (1%), demonstrated the most optimal performance due to its high dissolution profile, which reflected an effective release of the active compounds. In addition, the study included comprehensive preformulation and formulation evaluations, thereby providing a thorough overview of the dosage form quality. The superior performance of this formulation was attributed to the appropriate combination of excipients, particularly the use of two types of diluents, namely lactose and microcrystalline cellulose. Lactose, owing to its high water solubility, facilitated faster dissolution, whereas microcrystalline cellulose improved flow properties and created a porous powder structure that enhanced liquid penetration. Furthermore, the inclusion of other supporting excipients, such as disintegrants and lubricants in balanced proportions, contributed significantly to efficient capsule disintegration and active ingredient release [6].

Overall, each formulation demonstrated its own advantages and limitations depending on the intended purpose of dosage form development [5-7,10,11]. Conventional formulations offered advantages in terms of simplicity and ease of manufacturing; polyherbal formulations provided the potential for broader pharmacological activities. In contrast, nano-based technologies exhibited superior capabilities in enhancing the stability and bioavailability of active compounds [5,7,11]. However, when evaluated based on the balance between physical quality, effectiveness of active ingredient release, and potential for industrial-scale development, the formulation containing ginger extract (15%), diluent I (45%), diluent II (39%), and lubricant (1%) may be considered the most representative formulation for further development as a ginger-based herbal capsule preparation that fulfills pharmaceutical quality standards [6].

Therefore, formulation strategies play an important role in determining the quality and effectiveness of pharmaceutical preparations, particularly concerning the stability and bioavailability of active compounds. Stability reflects the ability of a pharmaceutical product to maintain its chemical, physical, and therapeutic properties during storage. In contrast, bioavailability determines the extent of active compounds that reach the systemic circulation to produce pharmacological effects [12]. Accordingly, a ginger extract capsule formulation capable of providing an optimal balance between physical quality, stability, dose uniformity, and efficient active compound release may be considered the most promising formulation for further development as a modern herbal preparation that fulfills pharmaceutical quality standards and supports favorable therapeutic efficacy [12].

Factors affecting capsule quality

The quality of capsule formulations is influenced by various interrelated factors, including material properties, manufacturing processes, evaluation parameters, and storage conditions [5,6]. The physical properties of materials, particularly particle size and shape, play an important role in determining blend homogeneity and content uniformity of capsules [5]. A non-homogeneous mixture may lead to dose variation among capsules, thereby reducing product quality [5]. In addition, the flow properties of powders affect the capsule-filling process, as poor flowability may result in irregular capsule weights [11].

Moisture content is also an important factor because it affects the physical and chemical stability of capsules [6]. Excessive moisture content may cause the capsule shell to become soft, pliable, or sticky [6]. In contrast, excessively low moisture content may reduce the elasticity of the shell, causing it to become rigid, dry, and prone to cracking or breaking during handling and storage [6].

In addition to material properties, manufacturing processes such as mixing and capsule filling also influence the final quality of the formulation [11]. Inadequate mixing may result in uneven distribution of the active ingredient, whereas improper filling techniques may compromise capsule weight uniformity [11].

Furthermore, capsule quality evaluation is conducted using parameters such as weight uniformity, disintegration time, and dissolution testing [5]. Disintegration time indicates the capsule's ability to release the active ingredient, while dissolution testing describes the release rate and availability of the active ingredient for absorption by the body [5].

Environmental factors such as temperature, humidity, and light exposure during storage also affect capsule stability [6]. Inappropriate storage conditions may lead to degradation of the active ingredient as well as changes in the physical properties of the capsules, including color and texture [6]. Therefore, proper control of material properties, production processes, quality evaluation, and storage conditions is essential to ensure stable capsules that meet quality standards [5,6,11].

Ginger's opportunity as a global adaptogen

Ginger has potential as an adaptogenic agent supported by its gingerol and shogaol content, but its development still lags behind ashwagandha (*Withania somnifera*), which has succeeded in the global market [6,10]. A comparison of these two plants is presented in **Table 3**.

Table 3. Comparison of ginger (*Zingiber officinale*) and ashwagandha (*Withania somnifera*) potential

Parameter	Ginger	Ashwagandha
Active compounds	Gingerol, shogaol [6]	Withanolides [13]
Formulation technology	Wet granulation, direct compression [5,11]	Sustained-release, proprietary technology [14,15]
Bioavailability	96% release in 60 minutes [6]	38.5× increase after dose normalization [13]
Human clinical trials	Limited [6]	Extensive (n=126, stress reduction 41.6%) [14]
Global market share	Limited	USD 1.2 billion [15]

With the right formulation approach, especially capsule modification using superdisintegrants, microencapsulation technology, and bioenhancers, ginger has an opportunity to compete with global adaptogens [6,7]. Indonesia is the world's largest ginger producer [2]. Export opportunities are wide open if ginger capsule products meet international quality standards, including Indonesian National Standard (SNI), World Health Organization Good Manufacturing Practices (WHO-GMP), and halal certification [8]. The Indonesian pharmaceutical and health supplement industry needs to invest in the development of innovative ginger formulations to compete with global adaptogens such as ashwagandha in the international market [3,4,14].

Conclusion

This review highlights the potential of *Z. officinale* as a local herbal plant with antioxidant, anti-inflammatory, antidiabetic, and adaptogenic properties that may be developed into a competitive global herbal product. The reviewed studies indicate that solid dosage form technology, particularly capsule formulation, can improve the stability, usability, and release of active compounds such as gingerol and shogaol, with the formulation containing 15% ginger extract, 45% diluent I (lactose), 39% diluent II (microcrystalline cellulose), and 1% lubricant showing the most promising performance based on its dissolution profile and industrial applicability. However, ginger development in Indonesia remains limited by insufficient standardization, limited stability and dissolution data, and a lack of strong clinical evidence. Therefore, future development should focus on standardized bioactive marker content, comprehensive quality testing, advanced formulation strategies, and clinical validation to support the entry of Indonesian ginger capsules into the global adaptogen market.

Ethics approval

Not required.

Acknowledgments

None to declare.

Competing interests

All the authors declare that there are no conflicts of interest.

Funding

This study received no external funding.

Underlying data

No new data were generated in this study.

Declaration of artificial intelligence use

Authors confirmed that no artificial intelligence (AI) tools or methodologies were utilized at any stage of this study, including during data collection, analysis, visualization, or manuscript preparation. All work presented in this study was conducted manually by the authors without the assistance of AI-based tools or systems.

How to cite

Ginting OSB, Fathaniah SS, Barus NHB, *et al*. Modification of *Zingiber officinale* capsules using solid dosage form technology as an adaptogen to accelerate the entry of local herbs into the global market: A review. Narra Thera 2026; 1 (1): e8 - http://doi.org/10.52225/narrathera.v1i1.8.

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