KEMAS 22 (1) (2026) 132-142

Jurnal Kesehatan Masyarakat

http://journal.unnes.ac.id/nju/index.php/kemas

Innovative Cookies Based on Watermelon Rind and Okra: Nutritional Content, Total Phenolic Content, and Antioxidant Activity

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Article Info

Article History:
Submitted March 2026
Accepted July 2026
Published July 2026

Keywords:
Antioxidant activity; diabetes mellitus; functional food; okra; Watermelon rind

DOI
https://doi.org/10.15294/kemas.v22i1.45528

Abstract

The rising prevalence of diabetes mellitus (DM) in Indonesia is strongly associated with high sugar and low fiber intake. Developing functional foods offers a promising strategy to mitigate DM risk by providing nutrient-dense, bioactive-rich alternatives. This study evaluated the nutritional composition, total phenolic, and antioxidant activity of cookies formulated with watermelon rind and okra. This study is an experimental design conducted in 2024 using a Completely Randomized Design with three formulations (Watermelon Rind Flour: Okra Flour: Wheat Flour): P1 (25%:10%:65%), P2 (30%:15%:55%), and P3 (35%:20%:45%). Analyses included proximate composition, total phenolics (Folin–Ciocalteu), and antioxidant activity (DPPH method), conducted in triplicate and evaluated descriptively based on integrated nutritional and functional parameter assessment. Data were evaluated using One-Way ANOVA with a significance level of 5% (α = 0.05). All cookies met the Indonesian National Standards (SNI) for carbohydrates, protein, fat, crude fiber, and energy, but exceeded limits for moisture and ash content. The highest phenolic content (0.87 mgGAE/g) and antioxidant activity (5.03%) were observed in P3, showing a positive correlation between phenolic content and free radical scavenging. These findings suggested that cookies enriched with watermelon rind and okra had potential as functional snack products, offering both nutritional benefits and natural antioxidant properties, particularly for individuals with diabetes or those pursuing a health-conscious diet.

Introduction

Hyperglycemia caused by irregularities in insulin secretion is a hallmark of DM, a metabolic disorder. Diabetes problems can arise from chronic hyperglycemia, which can cause long-term harm and dysfunction of multiple bodily organs (Eid *et al.*, 2019; Lians *et al.*, 2025). This condition is also associated with impaired muscle quality and strength, as well as reduced physical performance (Alvina *et al.*, 2025). From 6.9% in 2013 to 8.5% in 2018, the prevalence of DM in Indonesia is rising (Kemenkes RI, 2018). In Palangka Raya City, the number of DM patients seeking treatment at primary health centers has sharply increased over the past six years. In 2020, a significant rise was recorded, reaching 7,615 reported cases (Dinas Kesehatan Kota Palangka Raya, 2020).

According to data from the Food and Agriculture Organization (2022), Indonesia is among the countries with the largest rice producers and consumers in the world, after

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pISSN 1858-1196
eISSN 2355-3596

China and India. White rice is the staple food for most of the population; however, it is often accompanied by additional carbohydrate sources in meals, such as instant noodles. Frequent consumption of sweet foods and beverages also contributes to an increased daily carbohydrate intake (Khusun *et al*., 2022; Rimbawan & Sari, 2020; Rusdi, 2023). According to the Riskesdas 2018, approximately 40.1% of the population reported consuming sweet foods, and around 61.3% consumed sugar-sweetened beverages more than once daily. In 2020, Indonesia ranked third among Southeast Asian countries in the highest consumption of Sugar-Sweetened Beverages (SSBs) (Handayani *et al*., 2026). Regular consumption of sweet foods or beverages containing artificial sweeteners can trigger obesity and hyperglycemia, which are major contributing factors to the development of diabetes mellitus and other chronic diseases (Hadjarati *et al*., 2026; Hakim & Sari, 2025).

Numerous local foods can be developed as alternative snacks with potential health-promoting benefits, including for individuals with DM. Watermelon and okra have been identified as having antidiabetic potential. Watermelon (*Citrullus lanatus* Linn.) is a widely consumed fruit, often served as a dessert or processed into fruit salads, puddings, and beverages. It is recognized as a natural source of antioxidants with a sweet taste and various health-promoting benefits (Syachriyani & Firmansyah, 2022). As a natural antioxidant, watermelon can neutralize free radicals and reduce cellular damage within the body. Watermelon flesh and rind can be utilized. Typically, only the red flesh is consumed, while the white rind is discarded. However, the rind also contains various essential nutrients (Ashoka *et al*., 2021).

Watermelon rind contains significant moisture, ash, carbohydrates, protein, and fat. In addition, watermelon rind also contains various phenolic compounds (Al-Sayed & Ahmed, 2013). Watermelon rind extract has been reported to inhibit α-glucosidase, an enzyme associated with elevated blood glucose levels (Ermawati *et al*., 2024). The primary compound in watermelon rind is the amino acid citrulline, accounting for approximately 60% of its dry weight. Citrulline is a non-protein amino acid present in high concentrations in watermelon. Citrulline acts as a precursor for nitric oxide (NO) synthesis, stimulates insulin secretion, and promotes glycogenesis in the liver, thereby helping reduce blood glucose levels (Gu *et al*., 2023). Watermelon rind can be converted into a high-value product by drying and easily incorporating its powdered form into food preparations (Hoque & Iqbal, 2015).

Okra is a vegetable widely used in traditional medicine. It contains essential vitamins, minerals, and dietary fiber. Okra is rich in dietary fibre, making it beneficial for digestive health and improving cardiovascular function. Its soluble fibre content can lower blood cholesterol levels (Elkhalifa *et al*., 2021; Gemede *et al*., 2015). High dietary fibre intake can help stabilize blood glucose levels (Mao *et al*., 2021). Additionally, okra has been found to contain five phenolic compounds: isoquercitrin, quercetin-3-O-gentiobioside, quercetin, protocatechuic acid, and rutin. Okra has potent antioxidant action and inhibits digestive enzymes (D.-T. Wu *et al*., 2020). According to research by Mokgalaboni *et al*., (2023), okra can be used as a dietary supplement since it helps people with type 2 diabetes manage their blood sugar levels.

These ingredients, rich in nutrients and antioxidant compounds, may offer health benefits for individuals with DM. Therefore, further development is necessary to be widely accepted as a food product. Cookies, in particular, are well-liked by all age groups. Currently, cookie products are being developed as alternative snack options for individuals with DM (Puspaningtyas *et al*., 2024). This study presents a novel cookie product made of okra and watermelon rind. The purpose of this study was to assess the phenolic content and antioxidant activity of each cookie formulation as well as the nutritional composition of the cookies, including moisture, ash, carbs, protein, fat, crude fiber, and calorie content.

Materials and Methods

The raw materials used in this study were watermelon rind albedo (white inner part) and okra, collected from Palangka Raya City, Central Kalimantan Province, Indonesia, with the criteria of being fresh and free from decay. Watermelon rind flour was prepared following the procedures described by Ashoka *et al*., (2021) and Naknaen *et al*., (2016) with modifications, while okra flour was prepared according to the method of Nugroho & Hariono (2022) with modifications. Each finely powdered sample was vacuum-packed and stored at room temperature for further processing. Cookie preparation was carried out based on the method of Dinasanti *et al*., (2025). This study received ethical approval from the Health Research Ethics Committee of Poltekkes Kemenkes Palangka Raya, with approval number 200/III/KE.PE/2024.

Proximate analysis was conducted on cookie formulations P1, P2, and P3. The analysis included measurements of moisture, ash, carbohydrates, protein, fat, crude fibre, and energy content. The results were compared with the national standard for biscuit products as specified in SNI 2973:2011. With minor adjustments, the techniques outlined by Pebrina *et al*., (2021) were used to analyze moisture, ash, carbs, protein, fat, crude fiber, and energy. Soxhlet extraction was used to identify the fat content, the Kjeldahl method was used to analyze the protein content, the gravimetric method was used to estimate the moisture and ash contents, and the difference method was used to compute the carbohydrate content. Protein, fat, and carbohydrate conversion were used to determine the energy content.

The total phenolic content was determined using the Folin–Ciocalteu reagent with UV–Vis spectrophotometry. The standard was gallic acid at concentrations of 5, 10, 15, 20, 25, and 30 μg/mL. Milligrams of gallic acid equivalent (mg GAE) per gram of dry sample weight were used to express the total phenolic content (Azuan *et al*., 2020; Najjar *et al*., 2022). Antioxidant activity was evaluated using the 1,1-diphenyl-2-picrylhydrazyl (DPPH) method (Mashar *et al*., 2025). All analyses were conducted in triplicate, and results were expressed as mean values. Data were analyzed using One-Way ANOVA (α = 0.05), and mean separation was performed using Duncan's post-hoc test, where values within the same row bearing different letters (a, b, c) are significantly different.

Scavanging activity (%)= x 100

(Kustiawan *et al*., 2022; Mohd *et al*., 2023)

Results and Discussion

The rising incidence of DM is primarily attributed to lifestyle factors and dietary patterns characterised by increased consumption of processed foods, particularly those high in sugar and fat (Puspaningtyas

TABLE 1. Proximate Analysis Results of Cookies Compared to the Standard (per 100 g)

Components	Mean ± Std. Dev			SNI
	P1	P2	P3	
Moisture Content (%)	14.60 ± 0.035[a]	13.92 ± 0.075[b]	12.66 ± 0.006[c]	Min 5
Ash Content (%)	3.81 ± 0.125[a]	3.17 ± 0.006[b]	3.60 ± 0.010[c]	Max 1.5
Carbohydrates (%)	37.10 ± 0.006[a]	35.79 ± 0.065[b]	36.72 ± 0.035[c]	Max 70
Protein (%)	9.99 ± 0.085[a]	9.35 ± 0.006[b]	10.48 ± 0.130[c]	Min 9
Fat (%)	34.52 ± 0.000[a]	37.79 ± 0.010[b]	36.55 ± 0.090[c]	Min 9.5
Crude Fiber (%)	7.20 ± 0.095[a]	7.65 ± 0.075[b]	9.63 ± 0.085[c]	Min 0.5
Energy (kkal/ 100 g)	456.25 ± 0.650[a]	476.95 ± 0.035[b]	465.43 ± 0.205[c]	Min 400

The data shows the mean ± standard mean error of readings taken in triplicate. Values within the same row sharing different letters (a, b, c) are significantly different according to Duncan's post-hoc test at α = 0.05.
Source: Primary Data, 2024

et al., 2020; Tahilramani & Sengupta, 2013). Cookies formulated with watermelon rind flour and okra flour represent a potential alternative for individuals with DM. These cookies are nutritionally valuable and offer health benefits.

Based on Table 1, the moisture content analysis showed 14.60%, 13.92%, and 12.66% for P1, P2, and P3, respectively. Statistical analysis indicated that the moisture content was significantly different across all formulations ($p < 0.05$), with P1 having the highest value and P3 the lowest. According to the Indonesian National Standard (SNI 2973-2011), biscuits' maximum allowable moisture content is 5% (Pebrina *et al*., 2021). All formulations had moisture contents exceeding the 5% standard. The high moisture levels may be attributed to the use of watermelon rind and okra as raw materials. Watermelon rind has a high moisture content, approximately 94.62% per 100 g in its fresh form, and around 10.72% per 100 g when dried (Arivuchudar, 2023; Hoque & Iqbal, 2015). Okra also has a relatively high moisture content, approximately 88.6% every 100 g (Gemede *et al*., 2015). In its dried form, okra contains approximately 9.63%–13.33% moisture per 100 g (Liu *et al*., 2021). The product's high moisture content may be due to the flour's strong water-binding capacity, which helps the finished product retain more moisture (Adeola & Ohizua, 2018). Moisture content in a product is closely related to its shelf life. High moisture levels are one of the key factors contributing to microbial spoilage. Water activity can significantly affect the stability of food products during storage (Normilawati *et al*., 2019).

The ash content analysis showed values of 3.81%, 3.17%, and 3.60% for P1, P2, and P3, respectively, with each formulation being significantly distinct. The highest average ash content was observed in P1, while the lowest was in P2. According to the SNI 2973-2011, the maximum allowable ash content in biscuits is 1.5%. All formulations had ash contents exceeding the 1.5% limit, indicating they did not meet the SNI standard (Setyawati *et al*., 2023). Ash content estimates the total mineral content in each amount of food. High ash levels are influenced by the mineral composition of the cookies (Kumsa & Haile, 2020). Calcium, magnesium, potassium, and phosphorus are among the minerals found in watermelon, a primary ingredient in the cookie recipe (Lubis *et al*., 2021). Additionally, okra is rich in minerals, particularly iron and zinc (Liu *et al*., 2021). The ash level of food products also reveals the inorganic residue left after the material is destroyed. When evaluating the cleanliness and purity of a food ingredient, ash level is a crucial factor (Pangestuti & Darmawan, 2021).

Carbohydrate content in the cookies was calculated using the by-difference method, yielding values ranging from 35.79% to 37.10%. Post-hoc Duncan testing confirmed that the carbohydrate values across all treatments were significantly different from each other ($p < 0.05$). Compared to the carbohydrate quality standard for biscuits set by SNI 01-2973-1992, all three cookie formulations fall within the acceptable range, allowing a maximum of 70%. Watermelon rind contains a relatively high amount of carbohydrates. In its dried form, watermelon rind contains approximately 56% carbohydrates per 100 g (Arivuchudar, 2023; Hoque & Iqbal, 2015). In contrast, dried okra contains approximately 8.20% carbohydrates per 100 g (Gemede *et al*., 2015). Another major ingredient used in large quantities is wheat flour. Wheat flour is the primary source of carbohydrates in cookies (Rieuwpassa *et al*., 2023). This finding is consistent with the results of this study, which showed the highest average carbohydrate content in formulation P1 at 37.10%. The proportion of wheat flour used in P1 was 65%, which was higher than in P2 (55%) and P3 (45%). Wheat flour contains carbohydrates, primarily starch, accounting for approximately 67–70%. As a carbohydrate-based ingredient, wheat flour is commonly used as the main raw material in cookie production (Bakare *et al*., 2020).

The main energy source for every cell in the body is carbohydrates. They supply energy for working muscles and fuel for the central nervous system. Only glucose can be used by red blood cells to generate cellular energy (Pushpa, 2020; Zhang, 2022). The quantity of carbs is a major predictor of glycemic response, but the quality is significant in the glycemic index and fiber content. For people with diabetes mellitus, there is no set recommendation for carbs. As a result, dietary recommendations ought to take into account individual glycemic responses, personal preferences, and other health goals (McArdle *et al*., 2016).

The average protein content of the cookies in formulations P1, P2, and P3 was 9.99%, 9.35%, and 10.48%, respectively. Duncan's post-hoc test revealed that P3 had a significantly higher protein content compared to P1 and P2 ($p < 0.05$). The protein content analysis indicated that all cookie formulations met the SNI standard for biscuits, which requires a minimum protein content of 9%, with values ranging from 9.35% to 10.48%. The highest average protein content was observed in the P3 cookies, at 10.48%. This may be attributed to the higher proportion of watermelon rind flour (35%) and okra flour (20%) used in this formulation. Dried watermelon rind contains approximately 10.18% protein per 100 g (Ashoka *et al*., 2021, 2022). The protein content in okra has been reported to range from approximately 10.25% to 26.16%. Compared to other fresh vegetables, okra (particularly its seeds) contains relatively high levels of protein (Liu *et al*., 2021). The amino acids in okra protein are primarily composed of aspartic acid and 11 other essential amino acids. Protein plays a crucial role in human nutrition. Amino acids build and repair body tissues, form hormones and enzymes, and serve as an energy source (Gemede *et al*., 2015). Various studies have highlighted the important role of dietary protein and its health benefits, including in the management of diabetes mellitus. Increased dietary protein intake has improved insulin sensitivity in individuals with type 2 diabetes (Mohan *et al*., 2023).

The fat content analysis of cookie formulations P1, P2, and P3 was 34.52%, 37.79%, and 36.55%, respectively. Statistical evaluation confirmed that the differences among all formulations were highly significant ($p < 0.05$), where P2 accumulated the highest fat content, followed by P3 and P1. According to SNI 2973-2011, the minimum fat content requirement for biscuits is 9.5%. This study's findings showed that watermelon rind flour contains approximately 2.37% fat (Ashoka *et al*., 2021) and okra flour contains approximately 0.20% fat (Gemede *et al*., 2015). Both main ingredients have relatively low-fat content; therefore, the high fat in the cookies is likely due to the use of margarine in the dough. Margarine is made from either vegetable or animal fats and, therefore, contributes significantly to the fat content of cookie products (Mamat & Hill, 2014). For individuals with diabetes, managing fat intake is essential for controlling blood glucose levels. It is recommended that dietary fat comprise 25–35% of total daily calories, emphasizing monounsaturated and polyunsaturated fats while reducing saturated and trans fats (Garonzi *et al*., 2021; Liu *et al*., 2017). Excessive dietary fat intake increases the risk of obesity and lipid profile disorders in individuals with type 2 diabetes (Safitri *et al*., 2024).

The average crude fiber content in cookie formulations P1, P2, and P3 was 7.20%, 7.65%, and 9.63%, respectively. The results demonstrate a significant and progressive increase in fiber content from P1 to P3 ($p < 0.05$), with all formulations exceeding the SNI limit for crude fiber in cookies, which is set at a minimum of 0.5%. The highest average crude fiber content was observed in the P3 cookies at 9.63%, likely due to the higher proportions of watermelon rind flour and okra flour used in the formulation, at 35% and 20%, respectively. Watermelon rind has a good crude fiber content. Watermelon rind flour has been reported to contain approximately 17.44% crude fiber (Ashoka *et al*., 2021). Research has shown that 100 g of okra flour contains approximately 11.97% to 29.93% fiber. Dietary fiber is abundant in okra. Dietary fiber can make the stomach more viscous, slowing gastric emptying, reducing food intake, encouraging weight reduction, and helping control blood glucose levels in people with diabetes mellitus (Gemede *et al*., 2015; Liu *et al*., 2021). Crude fiber can enhance intestinal function and facilitate digestion. Additionally, it lowers the incidence of diabetes mellitus and heart disease and aids in controlling body weight (Aini *et al*., 2022; Shaikh *et al*., 2019). Consuming fiber can also help control blood sugar levels (Garonzi *et al*., 2021; Liu *et al*., 2017). The caloric value of the cookies varied from 456.25 to 476.95 kcal per 100 g, according to the data. Duncan's post-hoc test validated that the caloric differences among all groups were statistically significant ($p < 0.05$). The P2 formulation had the highest average energy content (476.95 kcal), while the P1 formulation had the lowest (456.25 kcal). These figures exceed the SNI's minimal energy content for cookies, which is 400 kcal per 100 g. The caloric content is influenced by the nutritional composition of the cookies, specifically the amounts of fat, protein, and carbohydrates. The product's caloric value increases with the concentration of certain macronutrients (Kulthe *et al.*, 2014).

Plants naturally produce phenolic compounds, which are a broad class of secondary metabolites made up of one or more hydroxyl (-OH) groups joined to an aromatic ring (Dai & Mumper, 2010). These compounds include phenolic acids, flavonoids, tannins, stilbenes, and lignans, which are natural antioxidants (Lang *et al.*, 2024). The stability and shelf life of food products are improved, and oxidative damage to human cells and tissues is prevented by the antioxidant activity of phenolic compounds (Lorenzo & Munekata, 2016). Functional foods containing phenolic compounds are highly relevant for preventing non-communicable diseases and improving public health in general (Fekete *et al.*, 2025; Ma *et al.*, 2025). The total phenolic content of the cookies is presented in Table 2. A gradual increase in total phenolic content was observed from formulation P1 (0.66 mg GAE/g) to P2 (0.75 mg GAE/g), with the highest level found in P3 (0.87 mg GAE/g). Duncan's post-hoc test confirmed that the total phenolic content across all formulations differed significantly from one another ($p < 0.05$). This increase reflects the influence of incorporating functional ingredients rich in bioactive compounds, such as phenolic compounds (Shahidi & Ambigaipalan, 2015).

Formulation P3, which exhibited the highest phenolic content, contained more functional ingredients—35% watermelon rind flour and 25% okra flour. These ingredients are rich in flavonoids, tannins, and phenolic acids, all of which contribute to the total phenolic content in the final product (Al-Sayed & Ahmed, 2013; Wu *et al.*, 2022). Watermelon rinds have been reported to contain various phenolic compounds, the most abundant being 4-hydroxybenzoic acid (958.3 μg/g dry weight) and vanillin (851.8 μg/g dry weight) (Al-Sayed & Ahmed, 2013). The compound 4-hydroxybenzoic acid in fungi exhibits both antioxidant and antidiabetic properties (Nowacka *et al.*, 2014). The study by (Vong *et al.*, 2025) reported that the mushroom Pholiota nameko contains 4-hydroxybenzoic acid, which can potentially reduce palmitate-induced insulin resistance in C2C12 myotubes. Moreover, processing methods such as baking can affect the availability of phenolic compounds, either by degrading or transforming them into more bioactive forms (Altemimi *et al.*, 2017).

The antioxidant activity followed a pattern consistent with the total phenolic content. Formulation P3 exhibited the highest antioxidant activity at 5.03%, while P1 and P2 showed lower and relatively similar activities, at 2.30% and 2.29%, respectively (Table 2). Duncan's post-hoc test verified that there was no significant difference in radical scavenging activity between P1 and P2 ($p = 0.932$), as they shared the same statistical subset letter. This result indicates a positive correlation between the high phenolic content and the sample's ability to neutralize DPPH free radicals. As is well known, phenolic compounds act as effective hydrogen donors to neutralize free radicals, and this mechanism forms the fundamental basis of

TABLE 2. Total Phenolic Content and Antioxidant Activity of Cookies

Components	Mean ± Std. Dev		
	P1	P2	P3
Total Phenolic (mg GAE/g)	0.66 ± 0.010^{a}	0.75 ± 0.025^{b}	0.87 ± 0.055^{c}
DPPH Radical Scavenging (%)	2.30 ± 0.145^{a}	2.29 ± 0.050^{a}	5.03 ± 0.045^{b}

The data shows the mean ± standard mean error of readings taken in triplicate. Values within the same row sharing different letters (a, b, c) are significantly different according to Duncan's post-hoc test at α = 0.05.
Source: Primary Data, 2024

the DPPH assay (Baliyan *et al*., 2022).

Nevertheless, the overall phenolic content and DPPH scavenging activity observed in this study were relatively low compared to other studies using cookies enriched with polyphenol-rich fruits or vegetables (Altemimi *et al*., 2017; Kausar *et al*., 2024). This may be attributed to several factors, such as thermal degradation of phenolic compounds during the baking process, interactions with other components in the food matrix (e.g., proteins or starch), or the inherent characteristics of the phenolic compounds themselves (e.g., type and solubility) (Czajkowska–González *et al*., 2021; Rocchetti *et al*., 2022). Although the DPPH activity values were relatively low, the observed trend indicates potential for utilizing phenolic-rich ingredients in the formulation of functional cookies. Formulation P3, with the highest phenolic content and antioxidant activity, has the potential to provide additional health benefits compared to the other formulations. These findings support the idea that functional cookies can serve as a delivery medium for bioactive compounds, contributing to the development of antioxidant-rich snacks targeted at health-conscious consumers or specific population groups, such as individuals with metabolic disorders.

Conclusion

The use of watermelon rind flour and okra flour as base ingredients in cookie production influenced the nutritional and bioactive compound content across all formulations. All cookie formulations met the nutritional standards set by SNI in carbohydrate, protein, fat, crude fiber, and energy content. However, some parameters (moisture and ash content) did not meet the standards. Therefore, improvements in formulation and processing are necessary to produce cookies with a more optimal physicochemical quality and safety for consumption. Conversely, antioxidant activity and total phenolic content rose in proportion to the amount of functional substances supplied. The greatest values for antioxidant activity and total phenolic content were found in Formulation P3. This suggests that the additives' phenolic compounds enhanced the cookies' antioxidant capacity. This encouraging trend supports the development of cookies as a delivery system for natural bioactive ingredients. Even though the absolute antioxidant activity values remain relatively low compared to similar products using pure extracts, this positive trend supports the development of cookies as a delivery medium for natural bioactive compounds. Thus, cookie formulations based on watermelon rind flour and okra flour (particularly P3) can be developed as functional snacks that meet basic nutritional needs and offer added value as a natural source of antioxidants. Such products have the potential to contribute to natural antioxidant intake through the daily diet and serve as a healthy snack alternative for health-conscious consumers or individuals at risk of metabolic disorders. Further studies are recommended to optimize processing conditions and fortification strategies to enhance the functional value of these cookies.

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