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Optimization of Nutritional Content and Antioxidant Activity of Instant Porridge based on Parboiled Rice and Mocaf Flour Fortified with Red Spinach

Optimalisasi Kandungan Gizi dan Aktivitas Antioksidan Bubur Instan berbasis Beras Pratanak dan Tepung Mocaf yang Difortifikasi Bayam Merah

Zulfa Nur Hanifa[1]*, Esi Emilia[1]

[1]Nutrition Study Program, Faculty of Engineering, State University of Medan, North Sumatra, Indonesia

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Correspondent:
Zulfa Nur Hanifa
zulfanurh@unimed.ac.id

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ABSTRACT

Background: Instant porridge is a type of processed food that does not require cooking in its preparation. The use parboiled rice, mocaf flour, and red spinach in instant porridge production offers a viable alternative for developing nutrient-dense and antioxidant-rich processed foods. Parboiled rice, a modified rice variant, is selected for its low glycemic index and high nutritional value. Mocaf flour, a gluten-free alternative, is used to enhance the product's nutritional profile, while red spinach is added to boost the antioxidant content of the instant porridge.
Objectives: This study aims to investigate the proximate composition and evaluate the antioxidant activity of instant porridge.
Methods: The instant porridge was formulated with a composition of 70% parboiled rice, 30% mocaf flour, and 2% red spinach. Proximate analysis was performed to determine the moisture, ash, protein, fat, and carbohydrate content, following the methods outlined in the AOAC 1995 guidelines. Antioxidant activity was evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay to assess the porridge's free radical scavenging capacity.
Results: The instant porridge produced was found to have a high nutritional content. The antioxidant activity was evaluated based on the IC_{50} value, the instant porridge demonstrated a notable IC_{50} value of 73.28 µg/ml, indicating that it possesses strong antioxidant properties / indicating that it is categorized as a strong antioxidant. The nutritional and antioxidant properties of the instant porridge can be attributed to the main ingredients used in its production.
Conclusions: The instant porridge produced provided high nutritional content and antioxidant activity, making it a good choice for meeting daily nutritional needs.

INTRODUCTION

Instant porridge has become increasingly popular in modern times due to its convenience and ease of preparation, which eliminates the need for a complicated cooking process. As an instant food option, instant porridge can meet daily nutritional needs. In recent years, innovations in the development of food products based on local ingredients have continued to grow. The utilization of parboiled rice, mocaf flour, and red spinach is essential to enhance the nutritional value of instant porridge products.

Parboiled rice is a type of rice that has undergone a special processing technique, resulting in a lower glycemic index compared to other types of rice. Studies have shown that the incorporation of parboiled rice in various food products, including instant porridge, can reduce the glycemic response after consumption, making it a healthier option for individuals with special needs, such as diabetes patients[1]. Furthermore, the higher nutritional content of parboiled rice, particularly protein and fiber, makes it suitable for application in food products with enhanced nutritional value[2].

Mocaf flour (Modified Cassava Flour) is a gluten-free flour alternative that is rich in complex carbohydrates and dietary fiber. Several studies have demonstrated that mocaf flour not only increases the nutritional value of processed products but also improves the texture and stability of food products, including instant porridge[3]. Mocaf flour produced through the cassava fermentation process has been proven to have a higher fiber content than cassava flour, contributing to improved digestive health and reduced risk of metabolic disorders, such as dyslipidemia and obesity[4]. As a gluten-free and complex carbohydrate-rich flour, mocaf flour is suitable for use in various food products, including cakes and noodles[5]. Research has shown that mocaf flour can increase protein levels in processed products when combined with other protein-rich ingredients[6].

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The addition of red spinach (*Amaranthus Tricolor L.*) into the instant porridge formulation provides additional benefits in terms of antioxidant content. Red spinach is rich in bioactive compounds such as betacyanins, flavonoids, and polyphenols, which have been shown to exhibit strong antioxidant effects[7]. Previous study has also demonstrated that red spinach can reduce oxidative stress and the risk of degenerative diseases, such as cardiovascular disease and cancer, when consumed regularly[8].

Antioxidant activity in food products is essential, considering its role in preventing various degenerative diseases associated with oxidative stress. Previous study has shown that foods rich in antioxidants can contribute to long-term health and reduce the risk of disease[9]. Antioxidant activity in food is crucial combating oxidative stress and protecting the body from degenerative diseases. The DPPH method is commonly used to measure the antioxidant capacity of free radical scavengers[10].

In this study, instant porridge was formulated using parboiled rice, mocaf flour, and red spinach to enhance the nutritional content and antioxidant activity of conventional instant porridge. Proximate analysis and measurement of antioxidant activity using the DPPH method were performed to evaluate the nutritional value of the end product. The results of this study are expected to contribute significantly to the development of functional food products that meet daily nutritional needs while playing a role in preventing degenerative diseases.

METHODS

This research methodology was designed to evaluate the nutritional content and antioxidant activity of instant porridge produced using parboiled rice, red spinach and mocaf flour. This methodology encompasses several steps, starting from ingredient selection, followed by the production process of instant porridge, and culminating in laboratory analysis to determine the proximate content and antioxidant activity. The production of instant porridge uses the optimal formulation, consisting of 70% parboiled rice and 30% mocaf flour, supplemented with 2% red spinach, chosen based on the results of physical tests in previous studies11. The production process of instant porridge is illustrated in the flow diagram presented in Figure 1.

The materials used incluede parboiled rice, mocaf flour, red spinach, and sugar. The chemical used are DPPH, aquadest, n-hexane, H_2SO_4 0,325 N, concentrated H_2SO_4, H_2SO_4 0,02N, NaOH 0,1N, NaOH 1,25 N, NaOH 40%, $CuSO_4$, K_2SO_4, oxalic acid, mengsel, and 96% alcohol. The equipment used comprised a stove, boiling pan, stainless steel tray, blender, stainless steel spoon, 40 and 60 mesh sieves, digital scales, mixers, masks, cloth gloves, plastic gloves, medium plastic containers, polyethylene plastic, aluminum foil, Whatman 41 filter paper, filter paper, kjedhal tube, erlenmeyer flask, measuring cup, measuring flask, funnel, vacuum pump, beaker glass, porcelain cup, aluminum cup and drying oven.

The method employed followed the procedure outlined by the Association of Official Analytical Chemists (AOAC) 1995. Moisture content analysis was determined using the oven drying method, also known as the gravimetric method. Ash content analysis was determined using the dry ashing method, wherein the sample was burned at high temperatures (550°C) until it became ash. Protein content analysis was determined using the Kjeldahl method, which involved calculating the crude nitrogen content by breaking down proteins into nitrogen. Fat content analysis was determined by extracting fat using a non-polar solvent (hexane). Crude fiber content analysis was determined using the acid hydrolysis method. Carbohydrate content analysis (by difference) was determined using the formula 100% - (moisture content + ash content + protein content + fat content).

The antioxidant activity of instant porridge was measured using the DPPH method, which involved several stages. The initial stage entailed sample preparation, wherein instant porridge was diluted with a solvent (e.g., ethanol) to obtain an extract. The second stage involved mixing with DPPH reagent at a specific concentration and incubating for 30 minutes in the dark at room temperature. The final stage involved measuring the absorbance value using a spectrophotometer at a wavelength of 517 nm. The IC50 value (concentration required to reduce 50% of DPPH radicals) was calculated to evaluate the antioxidant strength. This research was conducted at the Food Technology Laboratory, University of North Sumatra, from March to April 2024. This study obtained approval for the health research ethics code No. 0215/KEPH-FMIPA/2024 on April 22, 2024, from the Research Ethics Committee of the Faculty of Mathematics and Natural Sciences, University of North Sumatra.

The data obtained from the proximate content and antioxidant activity tests are presented in tables. The results of the analysis will be compared with existing standards in the literature to evaluate the quality of the instant porridge produced. As this study used single treatment, further statistical analysis was not required.

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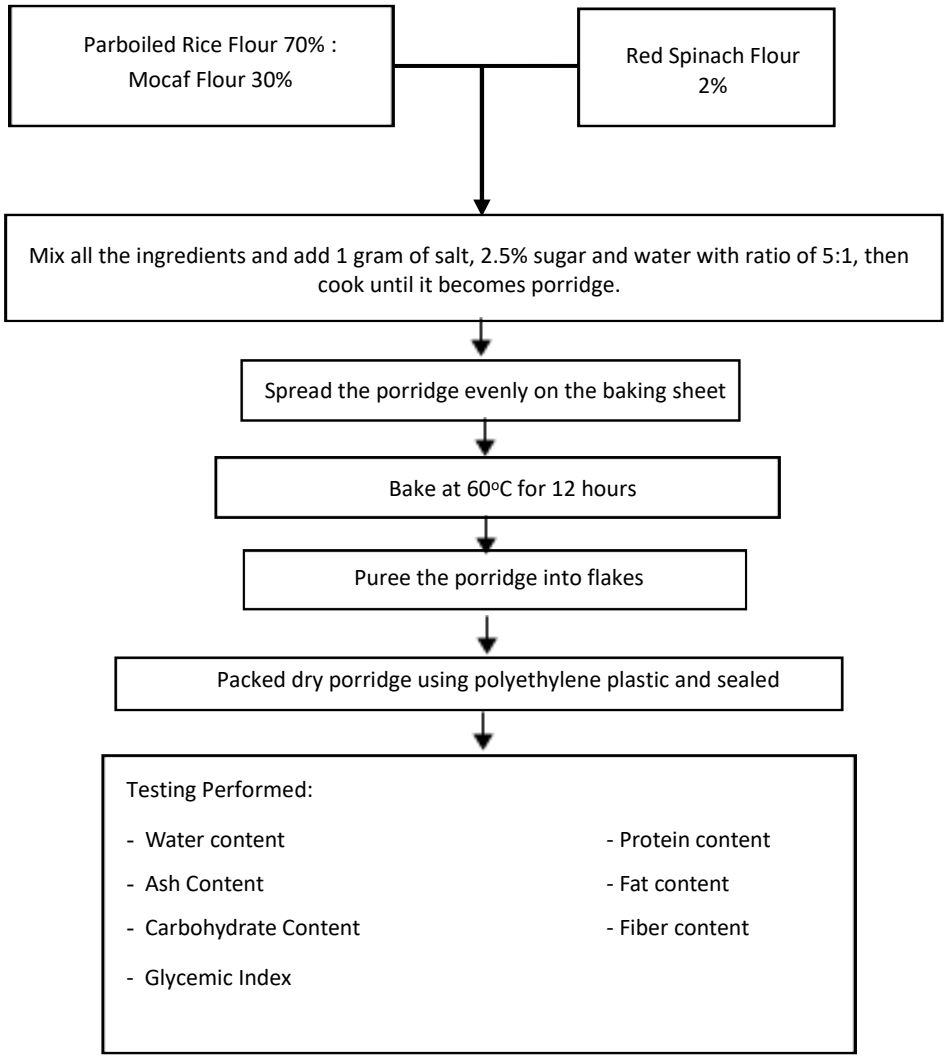

Figure 1. Instant Porridge Flow Chart

Figure 2. Instant Porridge Product

RESULTS AND DISCUSSIONS

Parboiled Rice

Parboiled rice is recognized for its superior nutritional profile compared to non-parboiled rice, as well as its lower glycemic index value. Additionally, parboiled rice possesses physicochemical characteristics that enhance its nutritional value. Previous studies have demonstrated that various types of rice, including parboiled rice, exhibit distinct nutritional compositions that can impact consumer health[12]. The results of the chemical characterization of parboiled rice are presented in Table 1.

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Table 1. Chemical characteristics of parboiled rice and non-parboiled rice

Characteristics	Parboiled Rice (%)	Non-Parboiled Rice (%)
Moisture content	5.95	11.20
Ash Content	0.72	0.50
Protein Content	9.44	7.00
Fat Content	1.89	0.70
Carbohydrate Content	81.98	78.90
Fiber Content	0.87	0.60

The parboiled rice characterization test reveals significant differences in the nutritional content of parboiled rice compared to its non-parboiled counterpart. Notably, parboiled rice exhibits higher concentrations of protein, carbohydrates, and fiber. This finding is corroborated by previous research, which demonstrates that the elevated amino acid content in parboiled rice substantially enhances its nutritional value by augmenting protein synthesis[13]. Furthermore, the protein content of parboiled rice is remarkably higher, at 9.44%, compared to non-parboiled rice, which contains 7.00% protein. This suggests that parboiled rice not only serves as a source of carbohydrates but also as a superior protein source, outperforming non-parboiled rice in this regard.

Mocaf Flour

Mocaf flour is a versatile flour that can serve as a 100% substitute for wheat flour, albeit with varying outcomes. Research has demonstrated that mocaf flour has the potential to replace wheat flour in baked goods, offering not only a reduction in wheat dependency but also enhanced nutritional value[14]. The physicochemical properties of mocaf flour have been extensively investigated. Previous studies have shown that mocaf flour possesses a composition that supports its use as a viable alternative to wheat flour, boasting superior nutritional content and acceptable organoleptic properties for consumers[15]. The characteristics of mocaf flour obtained are presented in Table 2.

Table 2. Chemical characteristics of mocaf flour

Characteristics	Amount (%)
Moisture content	6.52
Ash Content	0.72
Protein Content	4.48
Fat Content	1.59
Carbohydrate Content	86.69
Fiber Content	2.50

The results of the mocaf flour characterization test reveal that mocaf flour contains a relatively high fiber content of 2.50%. Previous research has shown that mocaf flour is rich in crude fiber, capable of meeting 20% of the daily recommended fiber intake. Furthermore, mocaf flour possesses a notable advantage: its gluten-free property. This makes mocaf flour an ideal choice for individuals with gluten allergies, including those with autism spectrum disorder[16]. Additionally, mocaf flour is known to provide benefits for individuals with degenerative diseases, owing to its high content of calcium and fiber[17].

Red Spinach

Red spinach is nutrient-dense vegetable, it is rich in including vitamins E, C, and A, protein, fat, minerals, fiber, iron, and magnesium[18]. Furthermore, previous studies have also indicated that red spinach is also rich in lutein, an important antioxidant compound that can be extracted from various parts of the plant, including the leaves[19]. Red spinach is also known to have antioxidant compounds, namely carotenoids, flavonoids, and polyphenols.[7]. According to previous research, the flavonoids presents in red spinach, such as quercetin, contain significant antioxidant activity and can contribute to health, including in the management of anemia[20]. The results of the chemical characterization test of red spinach can be seen in Table 3.

Table 3. Chemical characteristics of red spinach flour

Characteristics	Amount (%)
Moisture content	6.39
Ash Content	1.05
Protein Content	2.24
Fat Content	0.96
Carbohydrate Content	0.96

Antioxidant activity is expressed by the IC_{50} value. The IC_{50} value represents the concentration of the sample required by food ingredients to inhibit 50% of free radical activity. The higher the IC_{50} value, the lower the antioxidant activity. The IC_{50} value curve is determined based on the regression line equation between the concentration value of the test solution (x-axis) and the % inhibition of DPPH (y-axis).

Based on the analysis of antioxidant content, it can be seen that the average IC_{50} value of red spinach

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flour is 34.46 µg/ml. Based on the antioxidant activity strength classification, it is classified as very strong since the lower the IC_{50} value obtained, the higher the antioxidant activity, this is because the IC_{50} value of red spinach flour is below 50. According to previous research, the production of instant porridge with pumpkin fortification resulted in antioxidant value of 39% through the RSA method[21], and the antioxidant content of the instant red spinach porridge produced has stronger antioxidant activity.

Instant Porridge

Instant porridge made from red spinach, mocaf flour, and parboiled rice was measured its chemical characteristics. The chemical characteristics of the instant porridge produced can be influenced by several factors. Based on the results of the proximate and antioxidant content tests of the instant porridge, the characteristics of the instant porridge can be seen in Table 4.

Table 4. Chemical characteristics of red spinach flour

Characteristics	Amount (%)
Moisture content	5.51
Ash Content	1.53
Protein Content	9.55
Fat Content	2.28
Carbohydrate Content	1.90

Moisture content

The instant porridge made from mocaf flour and parboiled rice, fortified with red spinach, was analyzed to determine its proximate content and antioxidant activity. The results showed that the moisture content of the instant porridge was 5.51%. This relatively low moisture content indicates that the product has a longer shelf life potential, as high moisture content can increase product damage and deterioration[22]. Reducing moisture content can extend the shelf life of products and maintain the stability of protein and carbohydrate components, because high moisture content can cause degradation of nutritional components.[23].

The low moisture content in food products, such as instant porridge, contributes to better stability and shelf life. Previous research has shown that lower moisture content can reduce the risk of microbial growth and product damage, thereby increasing the product's resistance to spoilage and extending its shelf life[24]. The measured moisture content of 5.51% suggests that this instant porridge can be stored for a longer period without significant quality degradation. In contrast, high moisture content in food products can lead to rapid deterioration and quality degradation. Previous studies have demonstrated that products with high moisture content are more susceptible to mold and bacterial growth, resulting in quality degradation and reduced shelf life[25]. Therefore, the measured moisture content in this instant porridge indicates that the product has the potential to maintain its quality during storage.

Moreover, moisture content is closely related to the nutritional content in food products. Higher moisture content can dilute the concentration of nutrients, whereas lower moisture content can help maintain a higher concentration of nutrients. Research has shown that products with low moisture content tend to have better nutritional content, as the drying process can minimize nutrient loss caused by oxidation and degradation[26]. Therefore, the measured moisture content in this instant porridge contributes not only to product stability but also to better nutritional quality.

Ash Content

The test results revealed that the ash content of instant porridge made from mocaf flour and parboiled rice fortified with red spinach was 1.53%. This ash content provides valuable insights into the mineral content of the product, which plays a crucial role in various biological and health functions. Ash content serves as an indicator of the total mineral content in a food product. The measured ash content of 1.53% indicates that this instant porridge contains a significant amount of organic minerals. Previous study has demonstrated a direct correlation between ash content and mineral content in food products, which contributes to the overall nutritional value of the product[27]. The ash content determined through proximate analysis reflects the total mineral content in the product, highlighting its importance in food product development[28].

The measured ash content is also closely related to the overall nutritional value of instant porridge. Research has shown that products with balanced ash content tend to exhibit a more favorable nutritional profile, as the minerals present can contribute to overall health[29]. With an ash content of 1.53%, this instant porridge offers not only a source of energy from carbohydrates but also essential minerals that support overall health.

Protein Content

The test results showed that the protein content of instant porridge made from mocaf flour and parboiled rice fortified with red spinach was 9.55%. This protein content of 9.55% demonstrates that this instant porridge can significantly contribute to daily protein requirements. Protein is a vital macronutrient in food, essential for growth, tissue repair, and the production of enzymes and hormones. Foods rich in protein are crucial for supporting growth and development[30]. Previous research has shown that food products containing high protein can improve overall nutritional quality[31]. In this study, the use of parboiled rice as ingredient greatly contributed to protein content in instant porridge products, with protein content of 9.44% as seen in Table 1.

This instant porridge contains protein from diverse sources, including parboiled rice and mocaf flour.

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Mocaf flour, Mocaf flour, a cassava-derived product, has a higher protein content compared to regular wheat flour. Research by Fajriyah and Ilmi reveals that mocaf flour can serve as a viable alternative to increase protein content in food products[32]. Therefore, the combination of parboiled rice and mocaf flour in this instant porridge provides not only a source of carbohydrates but also sufficient protein to support overall health.

Fat Content

The fat content of instant porridge based on mocaf flour and parboiled rice fortified with red spinach was 2.28%. This amount of fat indicates that the instant porridge has relatively low fat content, making it an attractive option for consumers seeking to manage their fat intake. Fat serves as a vital source of energy; however, excessive fat consumption can contribute to health issues such as obesity and heart disease[33]. Previous research has shown that products with lower fat content tend to be preferred by health-conscious consumers[34].

The fat content in this instant porridge is derived from the ingredients used, including mocaf flour and red spinach. Although mocaf flour has a lower fat content compared to wheat, it still contributes to the fat profile of the product. Research has demonstrated that flours from plant sources, such as mocaf, can provide healthy fats essential for a balanced diet[35].

Furthermore, red spinach contains unsaturated fatty acids that are beneficial for heart health. Previous studies have shown that unsaturated fatty acids have a positive effect on lowering bad cholesterol (LDL) levels in the blood[36]. Therefore, the combination of parboiled rice, mocaf flour, and red spinach in this instant porridge provides not only a source of carbohydrates and protein but also healthy fats that are essential for maintaining good health.

Carbohydrate Content (by difference)

Based on the test results, the carbohydrate content of instant porridge made from mocaf flour and parboiled rice fortified with red spinach was 81.14%, indicating the instant porridge is a substantial source of energy. Carbohydrates are essential macronutrients for energy production. According to previous research, carbohydrates serve as the primary source of energy, and adequate intake is crucial to support daily activities[2]. The high carbohydrate content in this porridge can help meet energy needs, particularly for children and adolescents who require energy for growth and physical activity.

The carbohydrate content in this product was calculated using the by-difference method, a common approach for determining carbohydrate content in foods. This method involves measuring the moisture, ash, protein, and fat content, then calculating the remaining amount as the carbohydrate content[12]. Previous studies have demonstrated that this method is effective for calculating carbohydrate content in various food products, and the results are reliable for proximate analysis[14].

A high carbohydrate content can also impact the physical and sensory properties of the product. Previous studies have shown that foods with high carbohydrate content tend to exhibit better texture and are more preferred by consumer[37]. In this study, the carbohydrate content of 81.14% can provide a soft and chewy texture, which is expected to enhance consumer acceptance. However, it is essential to consider the balance between carbohydrates, proteins, and fats in the product. Previous study has emphasized that although carbohydrates are important, a balanced intake of all macronutrients is necessary to support optimal health[18].

The high carbohydrate content is also related to the Glycemic Index (GI) of the product. GI is a measure of how quickly carbohydrates in food can elevate blood glucose levels. According to previous research, the processing method and type of carbohydrates used can affect the GI of the final product[38]. In this study, the use of parboiled rice and mocaf flour, which have a lower GI compared to regular white rice, can provide additional benefits for consumers seeking to control their blood sugar levels. Based on the results of previous studies, the glycemic index value of the instant porridge produced is 50.51, categorizing it as a low-glycemic index product[1].

Fiber Content

The research result shows that the fiber content of instant porridge made from mocaf flour and parboiled rice fortified with red spinach was 1.90%. This amount of fibre can contribute to digestive health. Dietary fiber is well-known for its numerous benefits, including improving bowel movements, preventing constipation, and reducing the risk of colon disease. Previous study has demonstrated that fiber has the ability to prevent various problems in the digestive system, such as colitis[39].

Fiber also plays a crucial role in weight control. Foods high in fiber tend to induce feelings of fullness for longer periods, which can help reduce overall calorie intake. Research has shown that a high-fiber diet can increase satiety levels, contributing to weight control[40]. Therefore, with a fiber content of 1.90%, this instant porridge can be an excellent choice for those seeking to manage their weight.

The fiber content in this instant porridge is derived from the ingredients used, including mocaf flour and red spinach. The fiber content in the instant porridge produced is influenced by the ingredients used; to increase fiber content, a higher proportion of mocaf flour can be added. Mocaf flour, a cassava-derived product, has a higher fiber content compared to regular wheat flour. Research has demonstrated that flours from plant materials, such as mocaf, can make a significant contribution to fiber intake in food[41]. Additionally, red spinach is known to be rich in fiber, which can enhance the nutritional value of this instant porridge[7].

The high fiber content in this instant porridge can also impact the glycemic index (GI) of the product. The GI is a measure of how quickly carbohydrates in a food can raise blood glucose levels. Low GI foods have a more stable effect on blood sugar levels. Research has shown that parboiled rice, used in this porridge, has a lower GI than regular white rice, and the addition of fiber can further lower the GI of the final product[14]. Thus, the combination of good fiber content and the use of low GI ingredients can produce a healthier product for blood glucose management.

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Antioxidant Content

Antioxidant activity was determined using the DPPH free radical scavenging method. The purpose of testing antioxidant activity in instant porridge was to quantify the antioxidant content in the produced instant porridge. The IC_{50} value obtained from testing was 73.28 µg/ml. The incorporation of red spinach flour in the production of instant porridge significantly impacted antioxidant activity.

The measured antioxidant activity, represented by the IC_{50} value, indicates the concentration of extract required to inhibit 50% of free radicals in the test system. A lower IC50 value corresponds to stronger antioxidant activity. In this case, the IC_{50} value of 73.28 µg/ml suggests that this instant porridge exhibits considerable antioxidant activity. Research by Hidayati et al. demonstrates that products with low IC_{50} values can protect body cells from oxidative damage caused by free radicals, contributing to the prevention of various degenerative diseases, including cancer and heart disease[2].

The primary source of antioxidant activity in this instant porridge is attributed to the ingredients used, namely parboiled rice, mocaf flour, and red spinach. Red spinach, in particular, is rich in phenolic and flavonoid compounds, which are essential components of antioxidant activity. Previous study has shown that phenolic compounds can reduce free radicals, thereby enhancing antioxidant activity in food products[42]. Additionally, mocaf flour contains bioactive compounds, such as flavonoids and saponins, which can contribute to antioxidant activity.

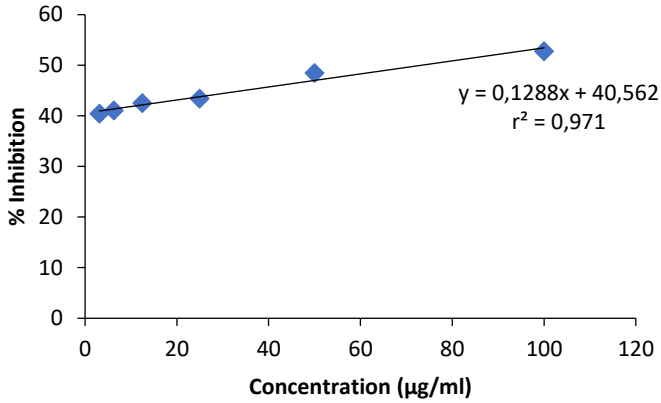

Figure 2. Graph (%) inhibition with concentration of Mocana Amoena instant porridge

Table 4. IC_{50} value of instant porridge best treatment

Concentration (µg/ml)	Inhibition (%)	IC50
100	52.77	72.28
50	48.51	
25	43.40	
12.5	42.55	
6.24	41.06	
3.12	40.43	

As presented in Table 6, the antioxidant activity value of instant porridge was 72.28 µg/ml, indicating that this product falls under the strong antioxidant category. This assertion is supported by Molyneux (2004), stating that the antioxidant activity value can be inferred from the IC_{50} value; the smaller the IC_{50} value, the higher the antioxidant activity or its efficacy in neutralizing free radicals. Specifically, antioxidants are categorized as very strong if the IC_{50} value is below 50 ppm, strong if the IC_{50} value is 50–100 ppm, moderate if the IC50 value is 100–150 ppm, and weak if the IC_{50} value is 151-200 ppm[2]. The primary source of antioxidant activity in this instant porridge is attributed to the ingredients used, namely parboiled rice, mocaf flour, and red spinach. Red spinach, in particular, is rich in phenolic and flavonoid compounds, which are essential components of antioxidant activity. Previous studies have demonstrated that these compounds possess the ability to reduce free radicals, thereby enhancing antioxidant activity in food products[42].

Red spinach used as ingredient contains flavonoid compounds, which exhibit excellent antioxidant properties. According to previous research, red spinach exhibits antioxidant activity due to its flavonoid content[20]. Red spinach has antioxidant content that can be used in the treatment of diabetes, cholesterol, and digestive problems, as well as reducing the risk of cancer. Red spinach is a natural antioxidant rich in protein, vitamins, mineral salts that are very much needed by the body, and also anthocyanins, which serve as colorant[8].

The results of this study indicate that the instant porridge produced exhibits promising potential as a rich source of antioxidants. High antioxidant activity is crucial, as it can help protect body cells from oxidative damage caused by free radicals, which contribute to various degenerative diseases, including cancer and other diseases.

This study offers the advantage of providing insight into the nutritional content of instant porridge made from parboiled rice, mocaf flour, and red spinach,

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which has a low glycemic index content, making it a suitable reference for diabetic-friendly foods. However, this study has limitations, as it does not cover the physical characteristics and sensory acceptance of the instant porridge. Further research is necessary to investigate the physical characteristics and sensory acceptance of the produced instant porridge.

CONCLUSIONS

Based on the research findings, instant porridge made from mocaf flour and parboiled rice fortified with red spinach demonstrates promising potential as a nutritious and antioxidant-rich food. The high carbohydrate content (81.14%) positions this porridge as a substantial energy source, while the protein content (9.55%) and fiber (1.90%) contribute significantly to digestive health and support overall growth. The antioxidant activity value, with an IC50 of 73.28 µg/ml, categorizes this instant porridge as a potent antioxidant, capable of safeguarding the body against oxidative damage. The primary source of antioxidant activity is attributed to the ingredients used, particularly red spinach, which is rich in phenolic and flavonoid compounds. Therefore, given its favorable nutritional profile and high antioxidant potential, this instant porridge presents a healthy and nutritious option as a daily complementary food. Further research is warranted to investigate consumer acceptance and explore potential applications of this product in the food industry.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

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AUTHOR CONTRIBUTIONS

ZNH: conceptualization, investigation, methodology, data curation, writing review, and project administration; EE: validation, writing-review, and editing.

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