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Banana Blossom as a Novel Ingredient in The Zero Waste Strategy: Application in Flakes

Safinta Nurindra Rahmadhia [1], Meta Sari [1], Maulidya Eka Wahyudi [1], Ibdal [1], Aprilia Fitriani [1*], Ali Jebreen [2]
[1] Food Technology Department, Universitas Ahmad Dahlan, Indonesia
[2] Department of Medical Therapeutic Nutrition, Palestine Ahliya University, Palestine

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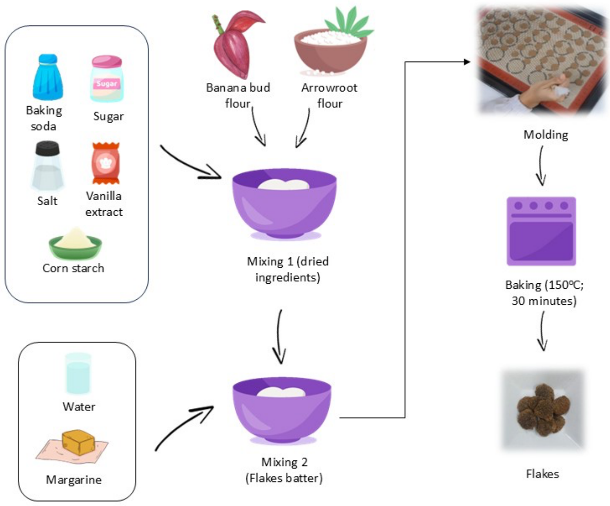
Corresponding Author:

Aprilia Fitriani,
Food Technology Department,
Universitas Ahmad Dahlan, Jl. Ahmad Yani, Tamanan, Banguntapan, Bantul, Daerah Istimewa Yogyakarta, Indonesia
Email: aprilia.fitriani@tp.uad.ac.id

ABSTRACT



Banana bud is an underutilized byproduct of the banana plant. Banana bud is rich in fiber and macronutrients that promote health. The potential of banana buds can be optimized by transforming them into convenient, ready-to-eat food products. This study contributed to facilitating the conversion of agricultural waste into nutrient-dense functional foods. This investigation will involve the preparation of flakes using banana bud flour and arrowroot flour as substitutes for wheat flour. Each mixture incorporated banana bud and arrowroot flour at concentrations of 5%, 10%, and 15%. Additionally, the flakes will undergo assessment of their chemical, physical, and sensory characteristics. The incorporation of banana bud and arrowroot flour into the flakes resulted in a considerable increase in total protein and crude fiber values compared to the control sample. The hardness and crunchiness of the flakes varied considerably, although the water absorption capacity rose markedly. The incorporation of banana bud flour resulted in the flakes acquiring a reddish hue. The outcomes of the descriptive sensory evaluation yielded an assessment of color, odor, texture, flavor, aftertaste, and texture after rehydration conducted by the panellists. The study's results indicate that banana plant waste can be utilized to produce nutrient-dense food products favored by panellists.

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1. INTRODUCTION

Bananas are a popular and widely consumed fruit. During the banana plant's growth process, the final stage produces nutrient-rich banana blossoms [1], [2]. In banana horticulture, the banana blossom is removed and discarded once the bunch has formed and its hands begin to ascend. Banana blossoms, also known as banana flower, banana inflorescence, banana heart, banana peduncle, or banana buds, are the consumable byproduct of banana cultivation, which have significant nutritional content [3], [4], [5], [6]. They comprise several bioactive substances and serve as a substantial source of crude fiber (5–6%), which aids in managing diabetes, facilitates weight loss, and promotes gastrointestinal health [7], [8]. The various benefits of banana blossom are explained in Table 1.

Table 1. Function of banana blossom.

Function	References
Anti-diabetes, anticancer, anti-inflammatory	[3], [7], [8], [9], [10], [11], [12]
Antioxidant	[10], [13], [14], [15], [16], [17], [18], [19]
Inhibiting the non-enzymatic glycation of proteins	[20], [21], [22]
Therapeutic potential	[23], [24]
Source of fiber	[13], [25], [26]
Development in the health sector	[27], [28]

In Indonesia, banana buds are primarily consumed as vegetables. Given their rich nutritional content, they should be processed into nutrient-rich foods that a wide range of people can consume. In various studies, banana blossom has been developed into functional products as described in Table 2. Convenient foods that are flavorful and nutritionally beneficial are consistently preferred by individuals of all ages [29], [30], [31], [32]. Baking products enjoy widespread popularity globally. The bakery food industry is rapidly becoming one of the main sectors in the global food market. The demand for bakery items (bread, cake, biscuits, cereal, flakes, etc.) is rising daily at an annual rate of 10.07% [1], [33], [34]. In various studies on banana blossoms, there has been no research that processes banana blossoms into ready-to-eat products such as flakes.

Table 2. Banana blossom application.

Product	References
Sandwich filler	[35]
Carbon dots	[36]
Fermented food	[37]
Cake	[1], [38]
Salad	[39]
Dehydrated vegetable	[26]
Sausages	[40]

Flakes are a ready-to-eat meal frequently eaten for breakfast because they can be consumed directly after purchasing or need little preparation before consumption [35], [41], [42]. Commercially produced flakes are often composed of wheat flour and corn flour, commonly referred to as corn flakes. The incorporation of additional functional elements into flake production leads to substantial alterations in both the quantitative and qualitative characteristics of the final flake products, which directly affect functional attributes such as water retention, stability, and texturization [43], [44]. It is advantageous to partially or completely substitute wheat flour to enhance the nutritional value of the product. Substituting wheat flour with alternative flours has been claimed to enhance the functional and nutritional attributes of baked products [45], [46], [47], [48]. The incorporation of banana bud flour into flake manufacture is a nutrient-dense culinary innovation and a viable alternative for the utilization of agricultural waste. To enhance the texture and nutritional quality of flakes, tuber flour may be used as a substitute for wheat flour [49].

Arrowroot is an enormous perennial herb found in tropical woods, characterized by its high starch content and significant commercial value [50], [51]. Arrowroot flour serves as a carbohydrate source and possesses a low glycemic index, making it suitable for intake by specific individuals [52], [53]. The starch level in the rhizome of arrowroot fluctuates with the plant's age, averaging around 20%, of which approximately 20–30% consists of amylose [54], [55]. In numerous food manufacturing applications, tuber flour is commonly utilized to substitute wheat flour [56]. Arrowroot has been extensively utilized as an ingredient in baked goods, ice cream, gelatin, and infant nutrition [57], [58]. Nevertheless, its capacity for generating flakes has not been extensively examined. Due to its good digestion, arrowroot is useful for infants, the elderly, people with digestive difficulties, and those with celiac disease [55].

The production of flakes utilizing banana bud flour and arrowroot flour represents a significant advancement in high-nutrient food innovation. This research contributes to the utilization of agricultural waste to generate nutrient-dense functional flakes. Additionally, the flakes will undergo analysis of their physical and chemical properties to ascertain their nutritional composition. A sensory investigation will be performed to determine consumer preference for the flakes. Fruit residues serve as exceptional functional additives, enhancing or moderating organoleptic features such as odor, color, nutritional parameters, taste, and texture. Fruits provide nutritional advantages to the consumer while enhancing sensory attributes [59], [60].

2. METHODS

2.1. Flakes Production

The method for producing flakes begins with the flouring of *kepok* banana buds (KBB). The crushed KBB are immersed in 0.2% citric acid and thereafter steamed for 6 minutes at 70 °C. The KBB are subsequently dehydrated in a cabinet drier at 60 °C for 6 hours. The flour is processed using a grinder and subsequently sifted through an 80-mesh sieve. The KBB flour is afterwards combined with arrowroot flour and wheat flour in certain proportions. Additional substances utilized in the preparation of flakes include water (100 ml), maize starch (8% w/v), sugar (14.4% w/v), salt (0.58% w/v), baking soda (0.24% w/v), vanilla powder (0.24% w/v), and margarine (2.4% w/v) [61], [62]. Table 3 demonstrates the compositional comparison of wheat, arrowroot, and banana bud flour, while Figure 1 presents the flow of flakes production.

Table 3. The comparison of banana bud, arrowroot and wheat flour.

Materials	F0	F1	F2	F3
Wheat flour (% w/v)	40	20	20	20
Arrowroot flour (% w/v)	0	15	10	5
KBB flour (% w/v)	0	5	10	15

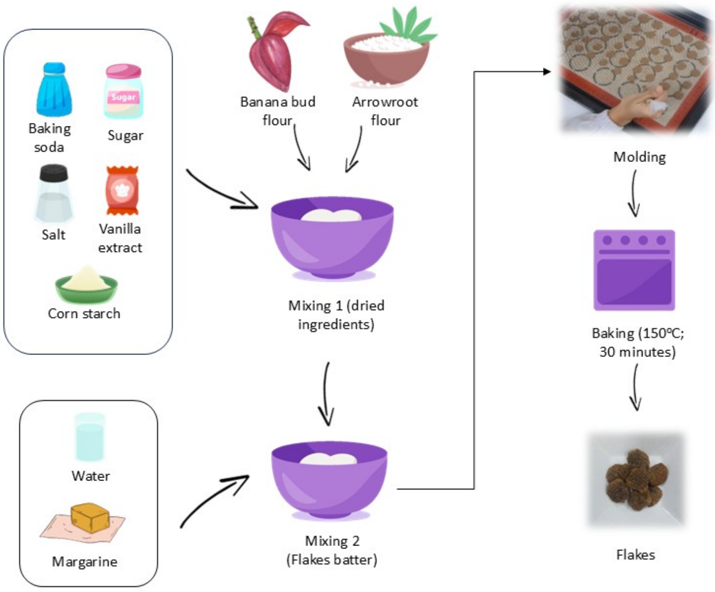

Figure 1. Diagram of the flakes production.

2.2. Total Protein Analysis

A 100 mg sample was utilized for total protein measurement in KBB flakes. The protein concentration in the sample was assessed by digestion, distillation, and titration methods [63], [64]. The determination of protein content in the sample was predicated on (1) and (2).

$$\%N = \frac{(A - B) \times NHCl \times 14}{sample\ weight} \times 100 \quad (1)$$

$$\%Total\ protein = \%N\ total \times 6.25 \quad (2)$$

Where A is the sample titration volume (ml), and B is the blank titration volume (ml).

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2.3. Crude Fiber Analysis

The crude fiber analysis method involves the sequential boiling of a sample in acid, followed by alkali to eliminate non-fiber constituents. After digestion, the residual fiber is filtered, desiccated, and weighed, after which the residue is burnt in a muffle furnace. The final computation involves subtracting the ash weight from the dry weight of the fiber residual and dividing the result by the original sample weight, reported as a percentage [65], [66].

2.4. Texture Analysis

Texture analysis was performed using a texture analyzer. Hardness and crispness values were obtained for each sample to determine the physical quality of the sample [67], [68].

2.5. Water Absorption Capacity Analysis

The gravimetric method has been used for water absorption analysis by submerging the sample in heated water. The sample was subsequently taken out, drained, and weighed to ascertain its water absorption value. The water absorption value was determined by dividing the mass before and after immersion by the original mass of the sample [69].

2.6. Optical Properties Analysis

Color analysis of flakes was performed using a chromameter. The color parameters determined were lightness (L^*), appearance (a^*), and blueness (b^*) [70], [71].

2.7. Sensory Evaluation Analysis

The sensory evaluation of flakes is conducted to assess consumer approval of the product by human senses or sensors [72], [73]. In food product research, the sensory characteristics of a product ultimately determine its acceptance or rejection [74], [75]. This study's organoleptic test involved 30 untrained panelists aged 20 to 23 years. Researchers disseminated a questionnaire concerning flake products via form. The established list of inquiries corresponded to the hedonic assessment (color, odor, texture, taste, aftertaste, and rehydration texture, along with overall evaluation) and descriptive analyses (color, aroma, texture, taste, aftertaste, and rehydration texture) [76], [77], [78]. The evaluation scale in the hedonic test of arrowroot flour flakes with the incorporation of KBB flour comprised (1) dislike, (2) slightly like, (3) like, and (4) very much like. The evaluative scale for flakes is presented in Table 4.

Table 4. Descriptive evaluation scale for KBB flakes.

Scale	Color	Odor	Texture	Taste	Aftertaste	Texture after rehydration
1	Brownish white	No arrowroot flour odor and no banana bud odor	Not crispy	Bitter	Bitter	Very soft
2	Brown	It has a slight odor of arrowroot flour and not banana bud	Slight crispy	Slight bitter	Slight bitter	Soft
3	Dark brown	No odor of arrowroot flour and has odor of banana bud	Crispy	Sweet	Sweet	Crispy
4	Blackish brown	Aromatic of arrowroot flour and banana bud	Very crispy	Very sweet	Very sweet	Very crispy

3. RESULT AND DISCUSSION

3.1. Total Protein of KBB Flakes

The protein in our diet serves as an energy source and fulfils additional functions, such as facilitating the transport of biochemicals across cellular membranes and catalyzing enzymatic activity. Furthermore, adequate protein from food consumption is a crucial nutritional element for the prevention of illnesses like sarcopenia in an ageing global demographic [79], [80].

Figure 2 indicates that the total protein content of KBB flakes increased significantly with the addition of banana bud flour. Flakes made from wheat flour had the highest protein content compared to the treated samples. This was due to differences in protein content in the raw materials. Arrowroot only has a protein content of 0.72% [55], while banana blossom has a protein content of 1.62–2.07% [37]. In research, banana blossom flour utilized for cake production showed a crude protein level ranging from 14.20% to 15.18%. Acid pretreatment of the banana blossom enhanced protein output [1], [81].

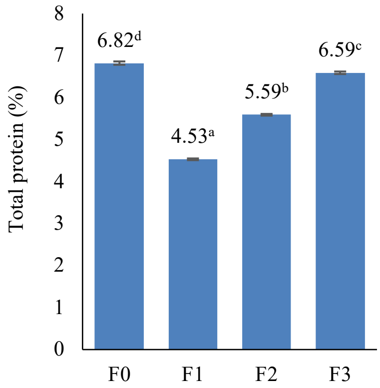

Figure 2. Total protein content of KBB flakes. Different notations indicate a significant difference at α=5%.

3.2. Crude Fiber of KBB Flakes

A notable rise in crude fiber content was seen in flakes enhanced with banana bud and arrowroot flour (Figure 3). Wheat flour flakes comprise merely 2.17% crude fiber, whereas KBB flakes possess 9.5–11.54% crude fiber. Banana bud is a fiber-rich byproduct, comprising around 5–6%, whereas arrowroot contains 1% [7], [8], [55]. Cakes prepared with banana blossom possess a greater crude fiber content compared to those produced with wheat flour [1]. This indicates that banana blossom may serve as a high-fiber food component. Dietary fiber is sourced from fruits, nuts, and vegetables. Vegetables with high fiber content, such as banana blossom, facilitate the digestive system, regulate body weight, and bind blood lipids and cholesterol [82], [83], [84].

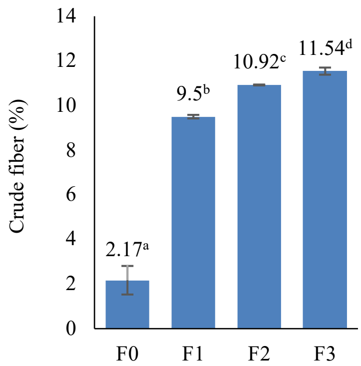

Figure 3. Crude fiber content of KBB flakes. Different notations indicate a significant difference at α=5%.

3.3. Texture of KBB Flakes

The textural properties of the flakes were examined for their hardness and crunchiness [85]. The values of hardness and crunchiness vary due to discrepancies in flake morphology (Table 5). Irregularities in flake morphology influence the overall texture of the flakes. An elevated hardness value signifies a more rigid and robust flake texture. A greater crunchiness score signifies a more rigid flake [82], [86], [87].

Table 5. Texture value of KBB flakes.

Sampel	Hardness (N)	Crunchiness (Nmm)
F0	2.90 ± 0.34^{b}	7.35 ± 2.77^{b}
F1	3.75 ± 0.01^{a}	15.66 ± 2.21^{b}
F2	4.03 ± 0.60^{a}	3.67 ± 0.08^{a}
F3	2.66 ± 0.21^{ab}	13.27 ± 0.93^{b}

Note: Different notations indicate a significant difference at α=5%.

Hardness denotes the strength or force necessary to bite and compress food [88]. It is a crucial element in food texture analysis, frequently evaluated by consumers to determine the quality and acceptance of a product [89], [90]. The hardness of bakery products is a significant concern, as the breaking strength of food items is a primary factor influencing consumer approval [91], [92]. Various elements influence the hardness of a baked product; however, in flakes, hardness is frequently associated with moisture content [93]. The structure and configuration of amylose and amylopectin influence the size and crystallinity of starch granules, impact water absorption, and alter the texture and crispness of cookies. Amylose, owing to its linear and little-branched structure, creates rigid helical complexes, yielding tougher and crispier cookies after baking, which attracts consumers who want a crunchier feel [94], [95].

3.4. Water Absorption Capacity of KBB Flakes

Water absorption capacity refers to a substance's ability to absorb and retain water, typically expressed as the ratio of absorbed water to the weight of the dry material [96]. The capacity for water absorption is influenced by several elements, including the material's composition—specifically its protein, starch, and fiber content—as well as its physical characteristics, such as moisture content, particle size, and porosity [97], [98]. Flakes with 15% banana bud flour added have the highest water absorption capacity value compared to flakes with 5% and 10% (Figure 4). A greater fiber content correlates with an increased capacity for water absorption [99], [100]. Fiber possesses a significant water absorption capacity owing to its complex structure and the abundance of hydroxyl groups capable of binding water molecules [101], [102].

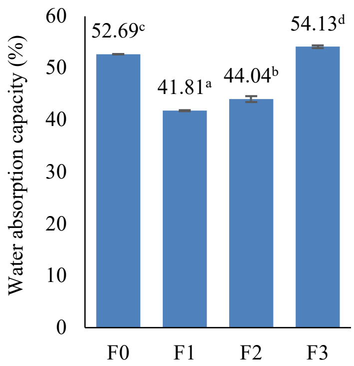

Figure 4. Water absorption capacity of KBB flakes. Different notations indicate a significant difference at α=5%.

3.5. Optical Properties of KBB Flakes

Color significantly impacted consumers' food selections and directly affected product marketing. The hue of food products was determined by the materials incorporated in their formulations [103], [104]. The optical characteristics of flakes are denoted by color variations, typified by alterations in L^*, a^*, and b^* values (Figure 5) [105]. The L^* value denotes the brightness of the flakes; thus, an increase in banana bud addition resulted in a considerable decrease in flake brightness (Figure 5). This signifies that the hue of the KBB flakes has deepened. Flakes without banana buds and arrowroot flour had the lightest hue. The a^* value in color analysis indicates the appearance of the flakes. A positive a^* value indicates a red color, while a negative value indicates a green color. Control flakes tended to have a greenish color, while flakes with banana bud flour tended to have a reddish color. A positive b^* value indicated a yellow color, while a negative b^* value indicated a blue color [106], [107], [108]. Control flakes had a significantly more yellow color than flakes with banana bud and arrowroot flour.

3.6. Sensory Evaluation of KBB Flakes

Table 6 illustrates the sensory assessment of flakes using KBB flour and arrowroot flour in comparison to wheat flakes. The panellists' evaluations indicated that the flakes exhibited a markedly enhanced colour score with the increase of KBB flour incorporation. F0 exhibited a brownish-white hue, whereas F3 exhibited a blackish-brown hue.

Table 6. Sensory evaluation of KBB flakes.

Sampel	Color	Odor	Texture	Taste	Aftertaste	Texture after rehydration
F0	1.00 ± 0.00^{a}	1.70 ± 0.89^{a}	3.27 ± 0.74^{a}	3.00 ± 0.74^{c}	3.07 ± 0.36^{d}	3.27 ± 0.64^{b}
F1	2.17 ± 0.53^{b}	2.93 ± 0.94^{b}	3.13 ± 1.01^{a}	2.80 ± 0.55^{c}	2.70 ± 0.59^{c}	3.23 ± 0.63^{ab}
F2	3.10 ± 0.61^{c}	3.07 ± 1.05^{b}	3.00 ± 0.95^{a}	2.47 ± 0.78^{b}	2.30 ± 0.79^{b}	3.20 ± 0.66^{ab}
F3	3.83 ± 0.38^{d}	3.22 ± 0.01^{b}	3.30 ± 0.65^{a}	2.00 ± 0.69^{a}	1.93 ± 0.64^{a}	2.90 ± 0.61^{a}

Note: Different notations indicate a significant difference at α=5%.

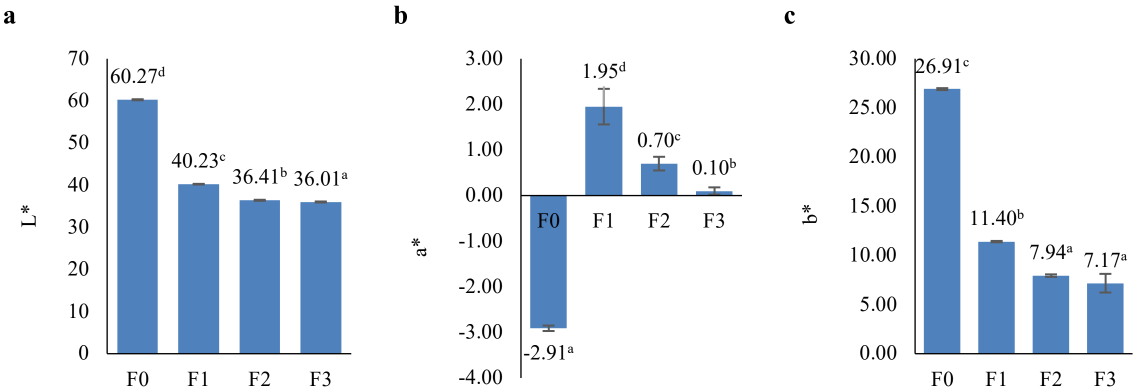

Figure 5. Optical evaluation of LBB flakes. Lightness (a), appearance (b), and brightness (c). Different notations indicate a significant difference at α=5%.

The incorporation of arrowroot flour and KBB provided the flakes with the odor of banana blossom flour and arrowroot flour. The panellists determined that the control flakes lacked the scent of both banana blossom flour and arrowroot flour. The texture of the flakes showed no significant differences between parameters. Therefore, according to the panelists, the flakes with the addition of KBB flour and arrowroot had a texture similar to wheat flour flakes.

The more KBB flour added to the flake formulation, the more bitter the flakes became. The bitterness in banana blossoms is caused by the tannins they contain. These polyphenols produce an astringent or bitter taste, similar to over-steeped tea [109]. The bitter flavour of the flakes influences the aftertaste upon consumption. F3 possesses a slightly bitter aftertaste in contrast to F0, which exhibits a pleasant aftertaste. The panellists indicated that an increased addition of KBB flour correlates with a heightened bitterness in the aftertaste.

Flakes that have been added with water or milk will produce a different texture than flakes consumed without water or milk. F3 has a softer texture after rehydration, compared to F0, which has a crispier texture. Texture after rehydration is related to water absorption capacity. The higher the water absorption capacity, the softer the texture after rehydration. However, the thickness of the sample also affects its texture after being dipped in water or milk [110], [111].

4. CONCLUSIONS

Based on the research conducted, it can be concluded that the use of banana bud flour in making flakes can improve the nutritional quality of the flakes. The total protein value and fiber content of flakes with the addition of banana bud flour increased significantly compared to the control sample. In addition, changes in chemical quality also affected the physical quality of the flakes. The texture and water absorption capacity of flakes with the addition of banana bud flour were significantly different from the control sample. The use of banana bud flour produced flakes with a brownish color. Based on the panelists' assessment, KBB flakes were acceptable by the panelists in terms of color, odor, texture, taste, aftertaste, and texture after rehydration.

DECLARATION

Sustainable Development Goals

The suitable development goals can be categorized as Zero hunger (SDG 2), Good health and Well-being (SDG 3), and Responsible Consumption and Production (SDG 12).

Author Contribution

All authors contributed equally to the main contributor to this paper. All authors read and approved the final paper. **Safinta Nurindra Rahmadhia**: Conceptualization; Methodology; Validation; Writing - Original draft; Supervision. **Meta Sari**: Investigation; Formal analysis; Writing - Original draft preparation; Software. **Maulidya Eka Wahyudi**: Investigation; Formal analysis; Writing - Original draft preparation; Software. **Aprilia Fitriani**: Writing - Reviewing and Editing. **Ibdal**: Writing - Reviewing and Editing.

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Conflicts of Interest
The authors declare no conflict of interest.

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