

# Sustainable Utilization of Agricultural Waste: Formulation of an Antioxidant Face Gel from Coconut Husk, Pineapple Peel, and Watermelon Rind

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## ABSTRACT

**Background:** The increasing generation of waste product has become a main environmental concern worldwide, especially due to the disposal of fruit residues such as rinds and peels. These agricultural by-products are rich sources of bioactive phytochemicals including phenolic compounds and flavonoids with potential antioxidant and cosmetic applications. The present study aimed to formulate and evaluate a moisturizing antioxidant face gel using extracts from watermelon rind (*Citrullus lanatus*), pineapple peel (*Ananas comosus*), and coconut husk (*Cocos nucifera*) as a sustainable waste management approach. **Materials and Methods:** Fruit peels were extracted using 96% ethanol through maceration, and the Total Phenolic Content (TPC) of the extracts was determined using the Folin-Ciocalteu method. Three gel formulations containing 1%, 2%, and 3% fruit peel extracts were prepared using Carbopol as a gelling agent and evaluated for physicochemical properties including stability, spreadability, gel strength, washability, and pH. Accelerated stability tests indicated that all formulations remained stable with no phase separation and maintained acceptable pH and homogeneity. **Results:** Among the extracts, coconut husk demonstrated the highest phenolic content (66 mg GAE/g), followed by pineapple peel and watermelon rind. In vivo evaluation using Sprague Dawley rats showed that the gel formulation containing 1% extract significantly improved skin moisture levels compared to the control group ( $p < 0.05$ ) without causing skin irritation. **Conclusion:** These findings suggest that fruit peel waste possesses significant antioxidant potential and can be utilized as a sustainable raw material for the development of skincare formulations while efficiently managing the agricultural food waste.

**Keywords:** Agricultural Waste, Antioxidant Face Gel, Coconut Husk, Cosmetic Formulation, Flavonoids, Natural Antioxidants, Phenolic Compounds, Pineapple Peel, Skin Hydration, Sustainable Utilization, Waste Valorization, Watermelon Rind.

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## INTRODUCTION

Global solid waste generation is projected to increase from approximately 2 billion tonnes in 2016 to about 3.4 billion tonnes by 2050 due to rapid urbanization, industrialization, and population growth.<sup>1,2</sup> Food waste represents a substantial proportion of municipal solid waste worldwide, with fruit and vegetable residues accounting for a significant fraction of this waste stream.<sup>3</sup> In Malaysia, food waste generation has been reported to exceed 17,000 tonnes per day, of which a considerable

portion consists of fruit and vegetable by-products such as peels, rinds, and seeds.<sup>4</sup> The accumulation of such organic waste poses serious environmental challenges including landfill burden, greenhouse gas emissions, and inefficient resource utilization.<sup>5</sup>

Malaysia is one of the major producers and consumers of tropical fruits, contributing significantly to the regional agricultural economy.<sup>6</sup> The processing and consumption of fruits such as pineapple, coconut, and watermelon generate large quantities of agricultural residues including peels, husks, and rinds.<sup>7</sup> These by-products are often discarded despite being rich sources of valuable phytochemicals including phenolic compounds, flavonoids, carotenoids, tannins, vitamins, and minerals.<sup>8,9</sup> Many of these compounds possess strong antioxidant, anti-inflammatory, and antimicrobial properties that may be beneficial for pharmaceutical, nutraceutical, and cosmetic applications.<sup>10</sup>



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Recent studies have emphasized the concept of waste valorization, where agro-industrial by-products are utilized as sustainable sources of bioactive compounds for value-added products.<sup>11</sup> Fruit peels have been particularly recognized as promising raw materials for the extraction of natural antioxidants and functional ingredients due to their high phenolic content.<sup>12</sup> These phytochemicals can scavenge free radicals, reduce oxidative stress, and protect biological tissues from damage caused by reactive oxygen species.<sup>13</sup> Oxidative stress has been widely associated with premature skin ageing, inflammation, and various dermatological disorders.<sup>14</sup>

Natural antioxidants derived from plant materials are increasingly preferred in cosmetic formulations because they are generally considered safer and more environmentally friendly than synthetic antioxidants such as Butylated Hydroxyanisole (BHA) and Butylated Hydroxytoluene (BHT).<sup>15</sup> Fruit peel extracts have demonstrated potential in improving skin hydration, reducing oxidative damage, and promoting collagen synthesis, thereby supporting their use in topical skincare formulations.<sup>16</sup> In addition, polyphenols and flavonoids have been reported to enhance skin barrier function and reduce trans epidermal water loss, which contributes to improved skin moisture and elasticity.<sup>17</sup>

Therefore, exploring fruit waste as a sustainable source of bioactive compounds may contribute not only to environmental waste reduction but also to the development of natural cosmetic formulations with antioxidant and moisturizing properties.<sup>18</sup> The present study aims to formulate and evaluate a moisturizing antioxidant face gel using extracts derived from coconut husk (*Cocos nucifera*), pineapple peel (*Ananas comosus*), and watermelon rind (*Citrullus lanatus*) as an approach toward sustainable waste management and natural skincare product development.

## METHODOLOGY

### Extraction

Pineapple peel, coconut husk, and watermelon rind was collected from AIMST university canteen, fruit sellers and Bazaar Ramadhan around Sungai Petani, Kedah. Collected young coconut husks, pineapple peel and red watermelon rind was washed using clean water to remove dirt. The powder was macerated using ethanol 96% at the ratio of 1:2 and was kept on mechanical shaker for 3 days in a cool dry place away from sunlight. Subsequently, it was filtered twice using muslin cloth and once using filter paper. Supernatant was collected and evaporated using rotary evaporator at 47 degrees and 110 rpm for 4 hr. Finally, the extract was placed in water bath until it solidifies. The extracts were placed in refrigerator at temperature 2 to 8°C until further testing was conducted. Percentage of yield is calculated using the following formula:

$$\text{Yield (\%)} = \frac{\text{Weight of the freeze - dried extract}}{\text{Weight of the dry ground peel}} \times 100$$

### Determination of Total Phenolic Content

Gallic acid was used as standard for the calibration of phenolics in this test. Standard solution was prepared by dissolving gallic acid in distilled water at concentration of 2, 4, 6, 8, and 10 µg/mL.<sup>19</sup> 1 mL of gallic acid of each concentration was added to 1 mL of Folin-Ciocalteu reagent and 4 mL of 7% Sodium Carbonate (Na<sub>2</sub>CO<sub>3</sub>) in a test tube. The blue colour mixture formed were observed, shaken well to mix and incubated at room temperature for 30 min. The absorbance was measured at 765 nm against the blank. Absorbance obtained at different concentration of gallic acid were used to plot the calibration curve.

Phenolic content as GAE was calculated using the formula:

$$\text{Phenolics content (mg GAE/g)} = \frac{C (\text{mg/mL}) \times V (\text{mL})}{m (\text{g})}$$

C is the concentration of gallic acid determined from the standard curve.

V is the volume of the extract (mL).

m is the mass of the sample (g).

### Face gel formulation preparation

Three different face gel formulation was prepared using different concentration of fruit peel extract and different proportions of excipients (Table 1).<sup>20</sup> Carbopol 940 and distilled water was heated in water at 70°C to allow gelling agent expansion. Methyl paraben and propyl paraben was added with distilled water and heated to dissolve. Triethanolamine was added dropwise to attain the pH of 6.8 to 7.0. Thereafter, distilled water was added up to 50 mL. Gel formulation was kept tightly closed in refrigerator (2 to 8°C) until further use.

### Physical testing of gel formulation

#### Centrifugation test

1 g of formulation was centrifuged at a speed of 3000 rpm for 30 min at room temperature. After 30 min, the presence of phase separation was observed. (+): phase separation. (-): no phase separation. If phase separation occurs, the formulation is considered unstable and vice versa.<sup>21</sup>

#### Spreadability

2 g of formulation was placed between 2 glass slides across a length of 5 cm. The slide on which the formulation was placed was fixed on the table surface while the upper slide was tied on one end with a string and connected to a simple pulley and pan. 20 g weight is loaded on the pan and the time taken for the upper slide to slide over 5 cm is measured. The spreadability of formulation was calculated using the following equation:<sup>22</sup>

$$\text{Spreadability} = \frac{m \times l}{t}$$

m=weight loaded on the pan (20 g) l=length of glass slides (5 cm).

t=time taken for slides to separate.

### Gel Strength Test

A 30 g weighted was gently put into the sample contained in a container of the same volume (50 g). The initial height (h1) was observed and recorded. The weight was allowed to sediment into the sample for 5 min. After that, the final height (h2) was observed and recorded. The height of sedimentation was calculated by using the formula:

$$h1 - h2$$

A higher number indicated lower gel strength.<sup>21</sup>

### Washability Test

0.5 g of sample was applied on a glass slide and washed under running tap water for 45 seconds. The flow rate of water was fixed at 25 mL/s. After washing, the glass slide was weighed to find out the weight of sample that remained on the glass slide (denoted as final weight, w2). The weight of sample lost due to washing was calculated using the formula:

$$w1 - w2$$

Higher value indicated higher washability.<sup>21</sup>

### Freeze-Thaw Cycle

The gel formulations were subjected to rapid temperature changes, starting with freezing temperatures of approximately -15°C for 24 hr, followed by thawing at room temperature for another 24 hr. Subsequently, the sample was exposed to higher temperatures of around 45°C for 24 hr before being returned to room temperature for an additional 24 hr. This was considered one cycle and a total of three cycles were conducted. The whole process took 12 days to be completed. After completing the three cycles, physical tests

such as pH, appearance, homogeneity and centrifugation test were carried out to evaluate the stability of formulations.<sup>21</sup>

### Moisture content determination

The experimental animals (Sprague Dawley rats) total of 20 rats with average weight 130-150 g was used in this research study. The animals were grouped into 4 groups and 5 rats in each group. Experimental animals were acclimatized for few days with a cycle of 12 hr of light and 12 hr of darkness, given enough food, and free access to water. The experimental animals (Sprague Dawley rats) total of 20 rats were shaved 5 cm × 5 cm on their back using the shaving cream. The shaving cream was applied on skin for 10 min, then it was completely washed out using wet cotton wool. The initial skin condition with various skin parameters (moisture content and oil content) after shaving was measured using a skin analyzer.<sup>23</sup> Gel was applied on the shaved area once daily for 14 days during the study period. Any changes in the animal skin during this study period was observed using magnifying glass.

### Statistical data analysis

Data were expressed as Means±Standard Error Mean (SEM) for five animal per group. Statistical analysis was performed by One-Way Analysis of Variance (ANOVA) and *post hoc* comparisons were done using Dunnett's *t*-test using SPSS computer software. The results were taken to be statistically significant at a probability level of  $p < 0.05$ .

## RESULTS

### Percentage yield of different fruit peel extract

Pineapple peel gives the highest percentage of yield followed by watermelon rind and coconut husk (Table 2).

### Total Phenolic Content of Different Fruit Peel Extracts

The total phenolic content of different fruit peel extracts is presented in Figure 1. Coconut husk showed the highest total

**Table 1: Composition of various gel formulations.**

Ingredients	F1	F2	F3
WRE (Watermelon Rind Extract)	1%	2%	3%
CHE (Coconut Husk Extract)	1%	2%	3%
PPE (Pineapple Peel Extract)	1%	2%	3%
Carbopol 934	2%	2%	2%
Methyl Paraben	0.0015%	0.0015%	0.0015%
Propyl Paraben	0.01%	0.01%	0.01%
Triethanolamine	Sufficient amount	Sufficient amount	Sufficient amount
Glycerin	5 mL	5 mL	5 mL
Distilled Water	Up to 50 mL	Up to 50 mL	Up to 50 mL

phenolic content followed by pineapple peel, combination of all three extract in 1;1;1 ratio and watermelon rind.

### Physical properties of Gel Formulations

The physical properties of gel formulation was presented in Table 3. The pH of all formulations is in the range of 5.80-6.45. There is no phase separation in all the formulations indicating the formulations prepared are stable. Pleasant natural odour was produced by all the formulations.

### Moisture content determination

The results for moisture content determination are shown in Figure 2. The results indicate that gel containing 1% fruit peel extract significantly improved skin hydration at  $p < 0.05$  compared with the control group begins from day 8 until the end of the study (Figure 2).

## DISCUSSION

The extraction yields obtained in the present study indicate that pineapple peel produced highest extract yield compared with watermelon rind and coconut husk (Table 2). Differences in extraction yield may be influenced by factors such as solvent polarity, extraction method, plant matrix composition, and geographical variation of plant materials.<sup>19</sup> Ethanol is widely used as an extraction solvent due to its efficiency in extracting both polar and moderately polar phytochemicals, while also being

relatively safe and environmentally acceptable for cosmetic and pharmaceutical applications.<sup>20</sup>

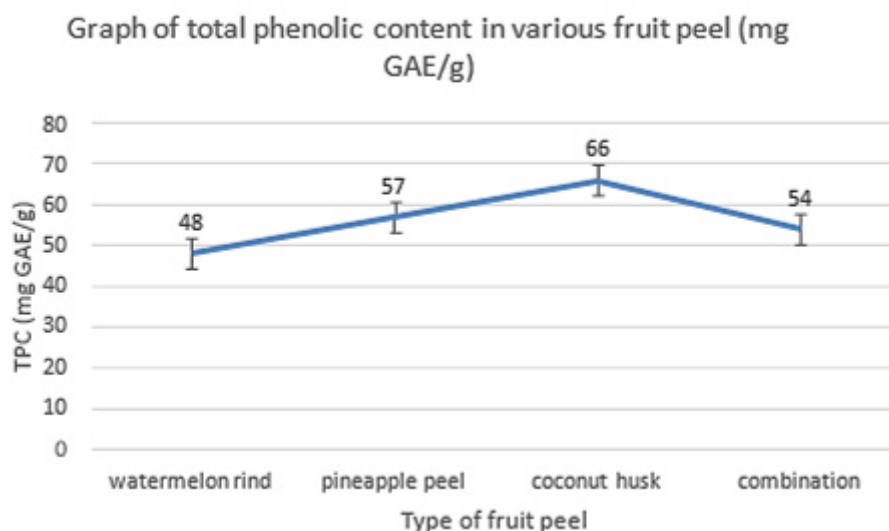
Flavonoids and phenolic acids play an important role in neutralizing reactive oxygen species, thereby protecting skin cells from oxidative damage and photoaging.<sup>21,22</sup> These compounds are also known to possess astringent and antioxidant properties that may help improve skin tightening and reduce the appearance of wrinkles.<sup>23</sup>

The total phenolic content analysis showed that coconut husk exhibited the highest phenolic concentration among the tested samples (Figure 1). High phenolic content is generally associated with strong antioxidant activity, which may enhance the protective effects of topical formulations against oxidative stress induced by environmental factors such as ultraviolet radiation and pollution.<sup>24</sup> Previous studies have also demonstrated that fruit peel extracts, particularly those from tropical fruits, contain significantly higher phenolic content compared to edible pulp portions.<sup>25</sup>

The stability studies indicated that the formulated gels maintained acceptable physicochemical properties including pH, homogeneity, and absence of phase separation (Table 3). Stability is a critical parameter in topical formulations because unstable products may result in reduced efficacy, microbial contamination, or skin irritation.<sup>26</sup> The pH values obtained in this study were within the acceptable skin compatible range, which is typically

**Table 2: Different type of fruit peel and percentage of yield.**

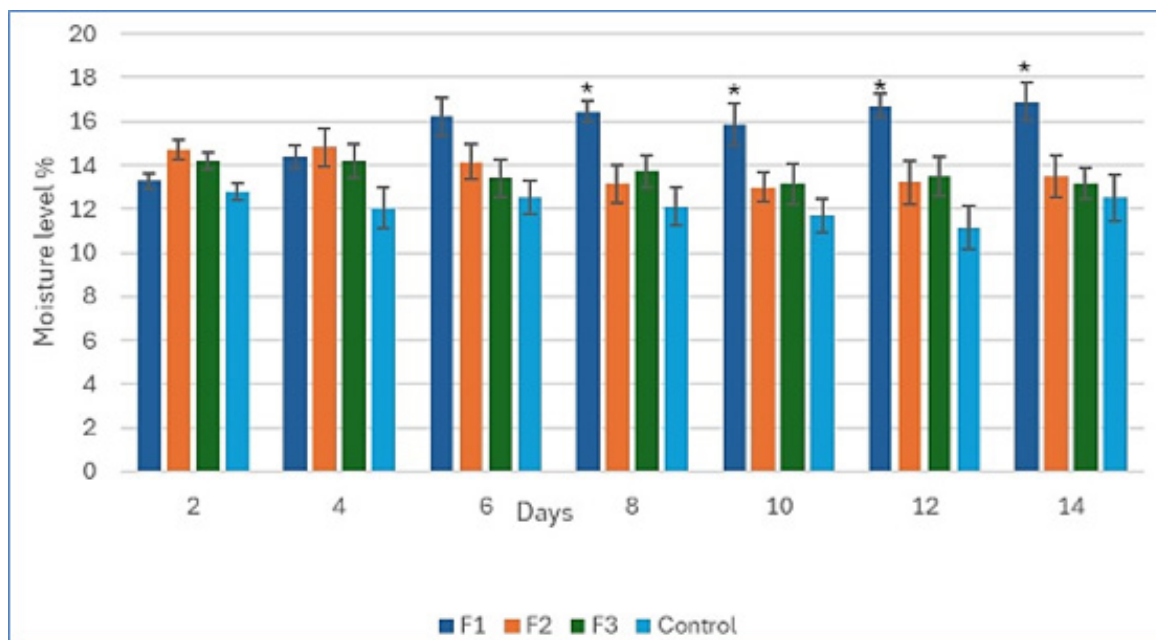
Type of extract	Powder weight (g)	Total extract (g)	Percentage of yield (%)
Coconut husk	480.7	45.9	9.5
Watermelon rind	490.5	50.3	10.3
Pineapple peel	523.0	63.12	12.1



**Figure 1: Total Phenolic Content in different fruit peel extract.**

**Table 3: Properties of Gel Formulations.**

Formulation	Parameters					
	pH	Homogeneity	Appearance			Phase separation
			Colour	Odour	Opacity	
F1	6.47	Poor	Brown (lightest)	Pleasant	Translucent	-
F2	5.89	Poor	Brown (darker)	Pleasant	Translucent	-
F3	5.95	Poor	Brown (darkest)	Pleasant	Translucent	-



**Figure 2:** Moisture level in Sprague Dawley rats after fruit peel gel application for 14 days. Results are presented as mean $\pm$ SEM ( $n=5$ ). \* indicates significant difference at  $p<0.05$  using Dunnett's  $t$ -test.

between pH 4.5 and 6.5 for topical cosmetic formulations.<sup>27</sup> Maintaining this pH range is essential for preserving the natural skin barrier and preventing irritation.

Moisture analysis demonstrated that the gel containing 1% fruit peel extract significantly improved skin hydration compared with the control group (Figure 2). Natural polyphenols and flavonoids present in fruit peel extracts may enhance skin hydration by strengthening the epidermal barrier and reducing transepidermal water loss.<sup>28,29</sup> Additionally, glycerin used in the formulation acts as a humectant that attracts moisture from the environment into the skin, further contributing to improved skin hydration.<sup>30</sup>

From a sustainability perspective, the utilization of fruit peel waste in cosmetic formulations represents an innovative strategy for waste valorization and circular bioeconomy development.<sup>31</sup> Converting agro-industrial residues into value-added skincare products not only reduces environmental pollution but also promotes sustainable resource utilization in the cosmetic and

pharmaceutical industries. Therefore, fruit peel extracts may serve as promising natural ingredients for eco-friendly cosmeceutical formulations.

## CONCLUSION

The present study demonstrated that fruit waste from young coconut husk (*Cocos nucifera*), pineapple peel (*Ananas comosus*), and watermelon rind (*Citrullus lanatus*) contains phenolic compounds with potential antioxidant properties. Among the extracts, coconut husk exhibited the highest total phenolic content, indicating strong potential for free radical scavenging activity. The formulated antioxidant face gel showed acceptable physicochemical stability and suitable characteristics for topical application. Overall, the findings suggest that fruit peel waste can be utilized as a sustainable source of natural antioxidants for the development of eco-friendly skincare formulations while contributing to waste reduction.

## ABBREVIATIONS

**TPC:** Total Phenolic Content; **GAE:** Gallic Acid Equivalent; **WRE:** Watermelon Rind Extract; **CHE:** Coconut Husk Extract; **PPE:** Pineapple Peel Extract; **ANOVA:** Analysis of Variance; **SEM:** Standard Error of Mean; **SPSS:** Statistical Package for the Social Sciences; **Na<sub>2</sub>CO<sub>3</sub>:** Sodium Carbonate; **rpm:** Revolutions per minute; **pH:** Potential of Hydrogen.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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