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Extraction of Lutein from Banana Peel via Ultrasound-Assisted Extraction Method for the Formulation of Antioxidant Soap

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Abstract

Banana peels are normally discarded, although they possess precious bioactive compounds like lutein, which is a xanthophyll-carotenoid pigment that has been found to possess a high antioxidant capacity. The goal of this work is to extract lutein from yellow and green banana peels using the Ultrasound-Assisted Extraction (UAE) technique and to determine the effect of ethanol concentrations (50% and 96%) on lutein extraction using UV-Visible spectroscopy at 450nm. Additionally, the lutein extracts from the UAE process will be analyzed with the use of Fourier Transform Infrared Spectroscopy (FTIR) to identify functional groups that are characteristic of carotenoids. The antioxidant capacity was determined using the DPPH assay at a wavelength of 517nm for all four lutein extracts (Y96, G96, Y50, and G50). The concentrated lutein extract was used to prepare an antioxidant soap using the cold saponification process, and the product was analyzed for its physical and chemical properties, which include pH (8-9), foamability (80%), foam stability (77.95%), moisture content (8.31%), and organoleptic tests, in addition to analyzing its DPPH radical scavenging activity (7.31%). The results of the work show that banana peels are a good source of lutein, and the UAE process is effective in the extraction of heat-sensitive compounds, in addition to contributing to the design of an environmentally friendly cosmetic material from agro-industrial waste.

1. Introduction

Banana peel is a big contributor to agro-industrial waste, which constitutes around 35% to 40% of the total weight of fruits [17]. Although a banana peel is considered a waste material, it has a high nutritional and bioactive component content, which includes phenolics, flavonoids, tannins, and carotenoids, with lutein, a xanthophyll pigment with potent antioxidant activity [3][7]. Research on the nutritional value of the banana peels grown in Malaysia has illustrated their value and therefore the need for their application in value-added applications and not for disposal as an organic waste [11].

Current interest in sustainable product development and the search for natural bioactive compounds, the use of banana peels as a material for the extraction of compounds has emerged. Ultrasound-Assisted Extraction (UAE) has emerged with positive attributes for the extraction of heat-labile compounds since the method facilitates the enhancement of mass transfer through acoustic cavitation and decreases the solvent and

extraction time required for the process [4][13]. Concentrations of ethanol are widely used for the extraction of compounds since the solvent is polar, safe, and efficient in the extraction of carotenoids including lutein [12]. UV-Vis spectroscopy with a wavelength of 450 nm can be used for the quantification of lutein in the substance, while FTIR helps to verify the functional groups responsible for the substance's bioactive compounds [8].

Due to the increasing demand for natural and biodegradable cosmetics worldwide, the use of plant-based antioxidants in cosmetics is becoming more important. The production of antioxidant soap from banana peel extract via the cold saponification process can help in the promotion of waste utilization and circular economy concepts by turning agricultural waste into useful cosmetics. Consequently, this research study entails the extraction of lutein from yellow and green banana peel samples via Ultrasound-Assisted Extraction (UAE).

The problem statement that has been obtained from the report is that the banana peels make up about 40% of the fruit's total weight and are commonly discarded, contributing significantly to agricultural waste. Despite being rich in phenolics, flavonoids, and carotenoids such as lutein, there is still limited research on extracting lutein from banana peels using Ultrasound-Assisted Extraction (UAE) and applying it in antioxidant soap formulations. Existing studies mainly extract other compounds like saponins, leaving a research gap in lutein extraction, characterization, and its use in skincare products. This study addresses this gap by exploring UAE, determining lutein characteristics, and evaluating its potential in antioxidant soap.

1.1 Literature Review

The banana peel extract is emphasized for its richness in carbohydrates, fiber, minerals, phenolics, flavonoids, and carotenoids, qualifying it for its valuable bioactive compound content rather than its waste material status [3][7]. The source and distribution of the banana peel make it ideal for large-scale extraction studies, and its chemical properties and bioactive compound content, particularly its content of lutein, make it an ideal material for antioxidant studies [11]. The method of extraction for this project is Ultrasound-Assisted Extraction (UAE), a method that takes advantage of the principle and mechanism of UAE, including knowledge of the components needed for an ultrasonic bath and the process followed for UAE [4][13]. Finally, rotary evaporation is a process that concentrated the ethanol from the other substances, removing it at a low pressure to leave a high-quality lutein. In compound identification, UV-VIS spectrophotometry is utilized for its ability to identify lutein at a specific wavelength [15], and its application is explained and supported by the comparison between using ethanol and ethyl acetate, a comparison that declared ethanol safer and more ideal [12][13]. However, its discussion on its use as a solvent adds further detail into its polarity, low toxicity, and effectiveness for phenolics and carotenoids [12][13]. The literature then turns its attention towards lutein, which is defined by its chemical structure and antioxidant function in protecting biological systems [8], and its application in banana peel based soap formulations has been demonstrated in previous studies [16]. Soap formulation using lutein then begins a discussion on basic antioxidant soaps, basic soap formulation agents, its role within the formulation, and a comparison between hot and cold processes, wherein the process takes a preferential stance within its preservation of a bioactive compound as demonstrated in banana peel–based soap studies [16].

2. Methodology

The methods utilized for the research include the selection of green and yellow peels of the Berangan banana, the sample preparation procedure which includes the steps of washing, cutting, drying, and grinding, and the extraction of lutein using the Ultrasound-Assisted Extraction (UAE) method. The extraction solvent utilized was ethanol at a concentration of either 50% or 96%, and the solvent was evaporated using the rotary evaporator at a temperature of 40°C and at reduced pressure. Laboratory analysis was done to establish the amount of lutein and functional properties in the extract. The amount of lutein was determined using UV-Visible spectroscopy at a wavelength of 450 nm, in addition to Fourier Transform Infrared Spectroscopy for functional group identification. The antioxidant properties of the extract were determined using the DPPH radical scavenging technique at a wavelength of 517 nm. In the formulation of products, the concentrated lutein extract was used to formulate the antioxidant soap through cold saponification involving the use of coconut oil, olive oil, shea butter, castor oil, and sodium hydroxide. The formulated soap was evaluated physicochemically to determine pH, foamability, foam stability, moisture content, and organoleptic test for color, texture, and fragrance. The antioxidant activity of the soap was also determined using the DPPH method.

2.1 Collection and Preparation of Banana Peel

The figure 1 shows the flow of collecting and preparing the banana peel. The fresh yellow and green "Berangan" bananas were bought from a local fruit seller at Panchor. The fresh fruits were used for the experiment rather than the mouldy, damaged nor spoilt banana peel (Figure 1-a). The bananas were cleaned to get rid of dirt as

well as to prevent any form of contamination (Figure 1-b). The pulp was extracted, and the yellow and green skins were chopped into small, equal bits with the use of a sharp knife (Figure 1-c). The discolored parts were cut off before drying the peels for further processing (Figure 1-d).

(a) **(b)** **(c)** **(d)**

Fig. 1: *Preparation of banana peels (a) Collection of yellow and green berangan banana (b) Separated banana pulp and the peels (c) Yellow and green banana peel (d) Chopped yellow and green banana peel in trays.*

2.2 Drying of Banana Peel

Banana peels were kept on different trays and weighed prior to the drying process with the objective of measuring weight loss and moisture removal in the peels. The trays were then set into the preheated drying oven with temperatures set to 45°C for 24 hours for the removal of excess water, since this temperature will prevent the destruction of heat-sensitive compounds. Banana peels were oven-dried for 45°C, a temperature suitable for minimizing degradation of heat-sensitive compounds [9]. After the completion of the process, the peels were inspected for even drying of the peels in preparation for blending into powder form and storage in an airtight container and kept under 4°C for the conservation of lutein.

2.3 Extraction of Lutein using UAE method

Figure 2 depict the step by step procedure of extraction of lutein using UAE method. Banana peels that were yellow and green were measured to weigh 25 g each and were placed in four labeled beakers (Y96, G96, Y50, and G50). A 1:10 w/v ratio was used, and two ethanol solution concentrations were prepared 50% and 96%. The 50% solution was made by mixing equal amounts of distilled water and ethanol. In turn, the 96% solution used more ethanol with little distilled water (Figure 2-a). These were labeled Y50, G50, Y96, and G96 and were prepared for Ultrasound-Assisted Extraction. The samples were mixed with 50% and 96% ethanol solutions. The beakers were placed in an ultrasonic bath at a temperature of 45°C for a period of 45 minutes (Figure 2-b)[6]. The sonication procedure followed the method reported in [6], using a standard laboratory ultrasonic water bath. The temperature and extraction time were controlled according to the referenced method to ensure consistent results. After extraction, the samples were covered and concentrated using a rotary evaporator at a temperature of 40°C, a pressure of 100 mbar, and speed of 100 rpm (Figure 2-c)[12].

(a) **(b)** **(c)**

Fig. 2: *Preparation of sample to extract using UAE method and remove solvent via rotary evaporator (a) Sample prepared for UAE method (b) Sample in rotary evaporator (c) Solvent removed from sample*

2.4 Determination of Lutein content using UV-Vis spectroscopy (450nm)

Table 1 shows the preparation of banana peel sample extract to conduct UV-Vis spectroscopy analysis using specific amount of mass of sample and volume of ethanol.

Table 1 *Preparation of banana peel samples extract for analysis.*

Sample	Ethanol Concentration (%)	Mass of banana peel (g)	Volume of Ethanol (mL)
Green	50	0.5	2.5

Progress in Engineering Application and Technology Vol. 7 No. 1 (2026) p. 698-709

Yellow	50	0.5	2.5
Green	96	0.5	2.5
Yellow	96	0.5	2.5

The concentrates were then diluted with ethanol (Table 1), which was used as the blank. The absorbance of all the samples was measured at a wavelength of 450 nm, which is the peak absorption point of lutein [15]. A 10% lutein extract obtained from marigold flowers was bought to be used as a reference material to make the calibration curve. The concentration of lutein for all the extracts was measured using the calibration curve to enable the eventual comparison of all the extracts made using 50% and 96% ethanol as well as yellow and green banana peels.

2.5 Determination of antioxidant activity using DPPH assay (517nm)

Table 2 shows the preparation of sample to conduct DPPH assay for antioxidant activity.

Table 2 *Preparation of DPPH for antioxidant activity analysis (517nm)*

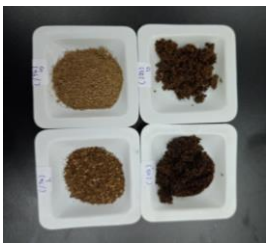
Sample	DPPH solution (mL)	Mass of banana peel (g)	Volume of Ethanol (mL)	Final Volume (mL)
Blank	0.0	0.0	3.0	3.0
Control (+)	2.9	0.1 (AA)	0.0	3.0
Control (-)	3.0	0.1	0.0	3.0
G96	2.9	0.1	0.0	3.0
G50	2.9	0.1	0.0	3.0
Y50	2.9	0.1	0.0	3.0
Y96	2.9	0.1	0.0	3.0

The antioxidant properties of banana peel extracts were determined by the DPPH radical scavenging method. The fresh solution of DPPH reagent in ethanol was used for the experiment, and ethanol was set as the blank. The reaction mixture of 2.5 mL of DPPH and 0.5 mL of extract was incubated for 30 minutes in the dark. Ascorbic acid at a range of 0.05 to 0.25 mg/mL was used as the positive control (Table 2). The absorbance was read at 517 nm after incubation to determine the percentage inhibition for the antioxidant activity of the extracts [1].

2.6 Characterization of extracted lutein using FTIR spectroscopy

Figure 3 shows the preparation of extracted banana peel to be analyzed by FTIR. Moreover, FTIR analysis was conducted to identify the functional groups of the lutein extracts (Figure 3-a). The dried samples were measured (Figure 3-b) between 4000-400 cm-1 to observe the prominent peaks for –OH, C-H, and C=C functional groups of lutein. The results were compared to determine the influence of maturity level of banana peel and concentrations of ethanol used. The FTIR peaks relevant to antioxidant activities verified that the extracted lutein maintained its identity as an antioxidant compound [6].

(a)



(b)

Fig. 3: *Preparation of sample for FTIR (a) FTIR device (b) samples of extracted banana peel*

2.7 Formulation of soap with cold saponification method

The cold saponification process was adopted in order to preserve lutein. Coconut oil, castor oil, olive oil, shea butter, NaOH, and distilled water were measured using a soap calculator. The preparation of the oils involved

melting shea butter. Lutein extract (3 g) and a couple of drops of essential oil were finally added to the soap mixture. The soap mixture was poured into a mould and cured at room temperature for a period of 8-12 days, as cold saponification helps in the preservation of bioactive compounds [2].

2.8 Physicochemical evaluation of soap

The soap was tested for quality and stability. The pH was tested by dissolving 1 g of soap in distilled water using pH paper. The pH for the antioxidant soap should be between pH 8 and 10 [13]. The organoleptic test was performed to examine the color, odor, and texture. The foamability and foam stability of the soap foams were determined by dissolving 1 g of cut soap samples in 10 mL of distilled water and measuring the foam volume after shaking the solution for 30 seconds and 1 minute, as well as for 5 minutes for foam stability [5]. The experiments were done three times for average results. For moisture content determination of soap, the soap was heated to a temperature of 104°C in an oven until a constant mass was reached. The soap was then cooled to determine its mass after moisture evaporation. The difference in mass showed the amount of moisture removed from the soap to obtain a stable soap product [10].

2.9 Analysis of DPPH Antioxidant Assay for Soap

The results for the antioxidant activity of the soap were obtained using the same reaction conditions for the free radical scavenging assay as for the extracts. For the soap solution preparation, 2.9 mL of the DPPH solution and 0.1 mL of soap solution were used, while ethanol was the blank and ascorbic acid the positive control. All mixtures were vortexed and subsequently incubated in the dark for 30 min, and using a wavelength of 517 nm were determine in measuring the scavenging activity [10].

2.10 Analysis of FTIR for Antioxidant Soap

The soap was chopped and weighted for 1 gram. The 1 gram piece of soap was placed on the sample dish and handed FTIR analysis was also applied to the formulated soap in order to recognize functional groups and to find out if there are any changes in peaks due to the absorption of lutein extract component in soap.

3. Result and Discussion

3.1 Drying Characteristics of Banana Peel

Table 3 shows the weight of banana peel sample before the oven drying and after the oven drying.

Table 3 *Weight of banana peel samples before and after oven drying*

Banana Peel Type	Initial Weight (g)	Final Weight After Drying (g)	Weight Loss (g)	Moisture Loss (%)
Yellow banana peel	2839.0	351.9	2487.1g	87.61%
Green banana peel	2839.0	501.5	2337.5g	82.33%

Figure 4 shows the yellow and green banana peel sample after dried in the oven dryer. The drying process was effective at reducing the moisture content of yellow and green Berangan banana peels (Figure 4-a). The yellow and green banana peels turned crisp and lightweight following oven drying at 45°C. Similar research has indicated that the removal of moisture enhances the efficiency of extraction and prevents the growth of microbes [17].

Fig 4: *Dried banana peel sample for both yellow and green*

Progress in Engineering Application and Technology Vol. 7 No. 1 (2026) p. 698-709

3.2 Determination of Lutein Content via UV-Vis Spectroscopy (450nm)

Table 4 shows the dilution of lutein standards from 0.05-0.25mg/mL and their absorbance at 450nm. The prepared standards were used to generate the calibration curve for determining lutein concentration in the extracts.

Table 4 *Preparation of standards stock and corresponding UV-Vis absorbance at 450nm*

Target Concentration (mg/mL)	Volume of stock (1 mg/mL)(mL)	Ethanol Added (mL)	Final Volume (mL)	Absorbance at 450nm
0.05	0.15	2.85	3.0	-0.073
0.10	0.30	2.70	3.0	-0.157
0.15	0.45	2.55	3.0	-0.178
0.20	0.60	2.40	3.0	-0.207
0.25	0.75	2.25	3.0	-0.228

The UV-Vis test verified that lutein is present in all four samples at 450 nm. Compared to other samples, Y96 had the highest absorbance intensity. Thus, it contains the highest amount of lutein. G96, Y50, and G50 followed. This experiment shows that 96% ethanol is more effective than 50% ethanol in extracting lutein from plants. This may be due to the higher solubility of carotenoids in concentrated ethanol, which improves the interaction between the solvent and lutein during extraction. Similar behaviour has been reported in ultrasound-assisted extraction studies, where solvent concentration significantly influences extraction efficiency [13]. In relation to this study's data, another study shows that lutein has strong absorbance intensity measured at 450 nm [15]. The working standards for lutein (0.05–0.25 mg/mL) were obtained by reducing a 1 mg/mL stock solution of the chemical with 3 mL of ethanol. A clear positive linear relationship was observed between concentration and absorbance at 450 nm, even though the values were shifted below zero due to baseline offset, indicating that the calibration curve was suitable for analysis. The negative absorbance readings can be attributed to over-correction of the blank or baseline drift. Although the absorbance values were negative, they still showed a consistent pattern as concentration increased. This means the instrument response remained proportional. Therefore, the calibration was used to compare lutein content between samples rather than to determine exact concentrations.

Table 5 shows that 96% ethanol, specifically G96, was able to extract more lutein compared to the others, while 50% ethanol had lower absorbance values for lutein, specifically G50, which contained the least amount of lutein.

Table 5 *UV-Vis Absorbance of Banana Peel Extract at 450nm*

Measurement No.	Sample	Abs	K Abs
1	Ethanol (Blank)	0.000	0.000
2	Ascorbic Acid	0.081	0.081
3	G96	0.101	0.101
4	Y96	0.054	0.054
5	Y50	0.037	0.037
6	G50	-0.224	-0.224

The lutein concentration of the banana peel extracts was assessed using UV–Vis spectrophotometry at 450 nm, with ethanol as the blank and using blank-corrected absorbance values for interpretation. The differences in absorbance were dependent on peel color and ethanol concentration used. G96 presented the highest absorbance value of 0.101, indicating more efficient lutein extraction compared to Y50, which showed a value of 0.054. Y50 presented a lower value of 0.037. G50 presented a value of −0.224, which may be attributed to baseline noise or blank over-correction rather than the absence of lutein (Table 5). The results suggest that increasing ethanol concentration enhanced lutein extraction, particularly for green peel extracts prepared with 96% ethanol [13][15].

Figure 5 depicts the visual changes of banana peel extract samples during the DPPH assay. The DPPH assay involves measurement of decolourization of purple DPPH by electron or hydrogen transfer from antioxidants, where greater colour fading indicates stronger antioxidant activity [1][10]. In this experiment, the negative control (DPPH solution with ethanol) was purple, which ensured there was no antioxidant effect, while the blank (pure ethanol) was transparent with no interaction. The positive control with ascorbic acid was light yellow due to high radical scavenging ability and served as a reference for effective antioxidant action. The extent of colour change of the banana peel extracts differed. The extracts obtained using 96% ethanol (G96 and Y96) contained lighter purplish-brown colours indicating stronger antioxidant activity. The 50% ethanol extracts (G50 and Y50) were darker in colour, indicating weaker activity (Figure 5-a). Y96 was the most decolourized sample among the extracts, followed by G96. The observation of colour change corresponds with the absorbance values at 517 nm and verifies that extracts with stronger antioxidant activity were associated with samples derived from 96% ethanol.

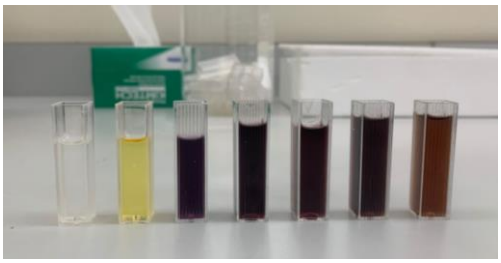


Fig 5: *Visual color changes observed during DPPH assay of banana peel extract samples in a cuvette*

Equation 1 shows formula for percentage inhibition

$$\%Inhibition = \frac{A_{control} - A_{sample}}{A_{control}} \times 100 \quad (1)$$

Table 6 *Result of DPPH Inbition Percentage*

Sample	Absorbance (517nm)	%Inhibition
Blank	0.000	-
Positive Control	0.067	74.9
Negative Control	0.267	-
G96	0.268	-0.37
G50	0.268	-0.37
Y50	0.268	-0.37
Y96	0.264	1.12

This indicates that the visible colors of the solution were decreasing in the banana extracts, but the calculation of the inhibition percentage of DPPH was relatively low at the used concentration (Table 6, Equation 1). The low inhibition percentage suggests that the antioxidant compounds present in the extracts were either at insufficient concentration or had limited hydrogen donating ability to effectively neutralize DPPH free radicals. This indicates that there could be weak hydrogen donors represented in the antioxidants or represented in the concentration that is not effective in scavenging the DPPH molecules. Similar observations have been reported in antioxidant soap studies, where extract concentration strongly influences radical scavenging efficiency [1][10]. However, the positive control, which is ascorbic acid, had higher inhibition, proving the accuracy of the DPPH result and confirming that the assay was functioning properly.

3.3 Characterize extracted lutein using FTIR Spectroscopy

Figure 6 shows the result of FTIR for Y96, G96, Y50, and G50 extracted banana peel samples, thus the wavenumber (cm^{-1}) as Y-axis and absorbance as X-axis. Moreover, FTIR analysis confirmed that the important functional groups found in all the extracts included O–H, C–H, C=C, C-O, and carbonyl functional groups that corresponds to cellulose, hemicellulose, pectins, and lutein-derived molecules found in banana peel biomass. The spectra obtained for Y96 and G96 were stronger and more defined in comparison to Y50 and G50, which signifies higher abundance of bioactive molecules. These observations agree with the results obtained from UV-

Progress in Engineering Application and Technology Vol. 7 No. 1 (2026) p. 698-709

Vis and DPPH analysis, which revealed higher lutein and antioxidant activities in Y96 and G96. The results obtained from FTIR analysis agree with previous findings in suggesting that higher ethanol concentration results in better extraction of lutein and bioactive compound.

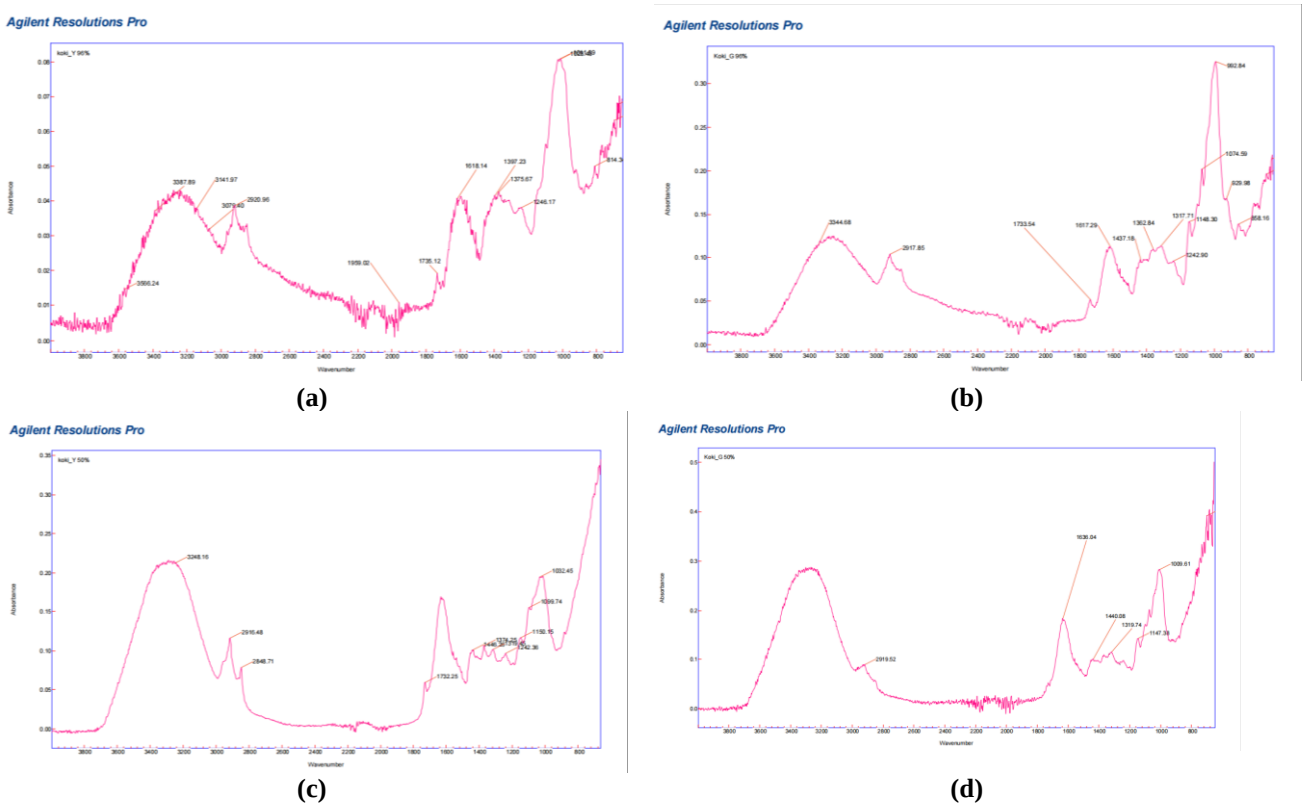


Fig 6: *Result of FTIR spectroscopy for banana peel sample (*wavenumber (cm^{-1}) as Y-axis and absorbance as X-axis*) (a) FTIR reading for Y96% (b) FTIR reading for G96% (c) FTIR reading for Y50% (d) FTIR reading for G50%*

3.4 Physicochemical and Organoleptic Evaluation of Soap

3.4.1 Organoleptic Test

Figure 7 depicts the banana-shaped soap made using the extracted banana peel. The soap had a firm and stable shape with smooth and grainy texture and light creamy color with spots, showing that the banana peel extract was uniformly incorporated into the soap matrix (Figure 7-a). It is hard but slightly squeezable, showing that the saponification process is successful and that the soap achieved suitable mechanical stability. It lathers well when rubbed with water and has a mild pleasant smell from the essential oil, without the strong smell of oil, confirming an acceptable appearance, texture, and scent consistent with reported characteristics of well formulated soaps [5][10].

Fig 7: *Banana soap formula was made using the extracted of banana peel*

3.4.2 pH Analysis

Figure 8 shows the pH measurement of the soap using pH paper. The result obtained from the pH determination test done using pH paper is an approximate value; in this case, the soap has a pH range of 8–9 (Figure 8-a,b), which is ideal for soap to be used and an indication that the alkaline soap has been properly formed. A pH within this range is important to ensure effective cleansing while minimizing potential skin irritation. This range corresponds with the pH range of most soap products (pH 9–10) [14], indicating that the prepared soap falls within acceptable commercial standards.

(a) **(b)**

Fig 8: *Measure of pH level of soap (a) pH level of 8 was obtained (b) pH level 9 was obtained*

3.4.2 Foam stability and foamability test

Figure 9 shows the foam stability and foamability test results, and Table 7 depicts the foam stability of the soap. Foam stability is the ability of the soap to maintain foam over time (Figure 9-a). For this analysis, the foam was tested using the shaking method. Measurements were taken at 30 seconds and 5 minutes, and the calculation was done using Equation (2). The values recorded for foam stability were between 75.90% and 81.71%, with a mean value of 77.95% (Table 7), which indicates that the lutein-enriched soap had a fairly stable lather. This suggests that the incorporation of banana peel extract did not negatively affect the foaming performance of the soap. This slight reduction in foam height may have been expected due to the aging process exhibited by the foam, as commonly observed in soap stability studies [5][10].

(a) **(b)**

Fig 9: *Result of foam stability and foamability test (a) Foam stability test (b) Foamability test*

Equations 2 and 3 show the formulas of foam stability and foamability.

$$Foam\ stability\ (\%) = \frac{Final\ foamheight}{Initial\ foamheight} \times 100 \tag{2}$$

$$Foamability\ (\%) = \frac{Initial\ \ foam\ height\ (cm)}{Liquid\ volume\ (mL)} \tag{3}$$

Table 7 presents the initial and final foam heights of soap along with the calculated foam stability for each replicate.

Table 7 *Foam stability of Soap*

Replicate	Initial Height (cm)	Final Height (cm)	Foam Stability (%)
R1	8.0	6.1	76.2
R2	8.2	6.7	81.7

R3	8.3	6.3	75.9
Average			77.95

Foam stability is the ability of the soap to maintain the foam (Figure 9-a). For this analysis, the foam was tested using the shaking method. Measurements were taken at 30 seconds and at 5 minutes and calculation was done using formula above (Equation 2). The values recorded for the foam stability were between 75.90% and 81.71%, with a standard mean value at 77.95% (Table 7), which indicates that the lutein enriched soap had a fairly stable lather. This slight reduction in height may have been expected due to the aging process exhibited by the foam.

Equation 4 shows the calculation of foamability test.

$$Foamability\ (\%) = \frac{8}{10} = 80\% \tag{4}$$

Foamability (Figure 9-b), an important functional property of soap, was tested using the shaking method for 30 s. An initial foam height of 8 cm, corresponding to 80% foamability (Equation 4), was obtained for the lutein-enriched soap preparation, indicating adequate formation of surface-active compounds during saponification. These surface-active compounds could align properly at the air–liquid interface, allowing effective foam formation as reported in soap performance studies [5][10]. In addition, the banana peel extract is rich in bioactive compounds, and their presence did not negatively affect foam production, showing that the bioactive materials did not interfere with foam formation.

3.4.3 Moisture content

Equation 5 shows the formula for moisture content

$$Moisture\ Content\ (\%) = \frac{Initial\ weight - Final\ weight}{Initial\ weight} \times 100 \tag{5}$$

Moisture content is one of the important characteristics of soap and affects the hardness and shelf life of soap. By using the oven-drying method at 102°C for 1 hour 30 minutes, the initial weight of the lutein-enriched soap was 16.25 g and the final dry weight was 14.90 g, resulting in a weight loss of 1.36 g. Based on the moisture content formula (Equation 5), the moisture content was calculated to be 8.31%, which is acceptable for homemade soap products [10] and indicates suitable stability for storage and use. A moderate moisture content shows that the soap is not too soft or brittle. Although banana peel extract contains hydrophilic components that may hold some moisture, the drying process helped remove excess water and ensured suitable physical quality of the prepared antioxidant soap.

3.5 Analysis of DPPH Antioxidant Assay for Soap

Table 9 shows the antioxidant activity of lutein-enriched soap was determined by a DPPH radical scavenging assy test, while the absorbance values at 517 nm and percentage inhibition are presented.

Table 8 Absorbance value for DPPH Radical Scavenging Assay for Antioxidant Soap (517 nm)

Sample	Composition	Absorbance	% Inhibition
Blank	Ethanol	0.000	-
Negative control	DPPH + Ethanol	-0.219	0.00
Positive control	DPPH + Ascorbic Acid	-0.054	75.34
Soap sample	DPPH + Soap solution	-0.203	7.31

The antioxidant activity of the lutein-enriched soap was determined using the DPPH assay at 517 nm, as shown in Table 8. The negative absorbance values were attributed to baseline drift or blank over-correction, and absolute values were used to calculate percentage inhibition. The negative control, consisting of DPPH in ethanol, showed the highest absorbance value (A0 = −0.219), confirming the validity of the assay. The positive control with ascorbic acid showed a much lower absorbance value (−0.054), corresponding to strong antioxidant activity with 75.34% inhibition [1][10].

The soap sample showed a reduction in absorbance (−0.203), corresponding to 7.31% inhibition. This indicates the presence of hydrogen-donating compounds in the soap capable of scavenging DPPH radicals. Although the scavenging activity was lower than the positive control, this was expected due to the lower concentration and limited mobility of antioxidant compounds after saponification. Overall, the results suggest that a portion of lutein and other bioactive compounds remained active in the formulated soap [1][10].

3.6 FTIR Analysis of Antioxidant Soap

Figure 10 represents the FTIR reading on the soap sample whereas the wavenumber (cm^{-1}) as Y-axis and absorbance as X-axis. The wide band corresponding to the 3200–3500 cm^{-1} range was attributed to the O–H stretching vibration, thus revealing the existence of hydroxyl groups from phenolic materials as well as water. The existence of the antioxidant functional groups from the banana peel extract in the soap was shown (Figure 10-a). The bands at 2918 cm^{-1} and 2848 cm^{-1} were attributed to the C–H stretching of the aliphatic groups $–CH_2$ and $–CH_3$, respectively. This is an indication that the soap was created through the saponification process. The peaks appearing at 1741 cm^{-1} are related to C=O bond vibrations due to the presence of either ester or carbonyl groups, whereas the peak appearing at 1556 cm^{-1} is related to C=C bond vibrations, which is typical for carotenoids like lutein. Other peaks appearing in the region 1444-1421 cm^{-1} are related to C-H bending in aliphatic compounds, whereas the peaks appearing in the region 1106-1045 cm^{-1} are related to C-O bond stretching in oxygen-containing compounds. Lower wavelength peaks appearing at 922 cm^{-1} and 853 cm^{-1} can be attributed to out-of-plane C-H bending in unsaturated compounds (Figure 10). The FTIR spectrum confirms the presence of both soap base functional groups and antioxidant related group indicating that lutein and other bioactive compounds from the banana peel extract were successfully incorporated into the soap without degradation.

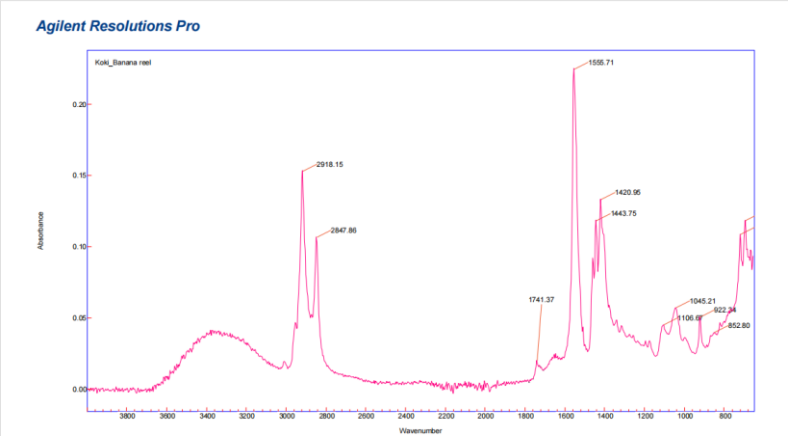


Fig 10: *FTIR reading of the antioxidant soap (wavenumber (cm^{-1}) as Y-axis and absorbance as X-axis)*

4. Conclusion

This study successfully extracted lutein from green and yellow banana peels using Ultrasound-Assisted Extraction (UAE) and confirmed its presence through UV–Vis and FTIR analysis. The lutein extract was effectively incorporated into an antioxidant soap using the cold saponification method, which preserved its bioactive properties. The formulated soap showed acceptable pH, good foamability and stability, suitable moisture content, and favourable appearance. Although the antioxidant activity in the soap was lower than the crude extracts, measurable DPPH scavenging confirmed that antioxidant compounds were retained after formulation. Overall, this research demonstrates that banana peels can be repurposed into a value-added antioxidant soap, achieving the objectives of extraction, formulation, and evaluation, and promoting the sustainable utilisation of agricultural waste. This effort aligns with SDG 12: Responsible Consumption and Production by supporting waste reduction and the valorisation of natural resources.

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