



## Research article

## Comparative study of polyphenolic compound extraction from empty palm fruit bunches and sugarcane pulp



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## ABSTRACT

Polyphenolic compounds have many benefits, one of which being their efficacy as antioxidants. They can be extracted from various parts of plants and from agricultural waste. In this research, sugarcane pulp, and empty palm fruit bunches from the palm oil production were investigated as potential raw materials. This study aims to determine solvents and easy-to-perform extraction methods that show the highest effectivity in regards to total phenolic and flavonoid yield and the correlated antioxidant activity. Extraction methods comprised maceration, Soxhlet extraction, and ultrasound assisted extraction (UAE); solvents that were investigated included water, 70% methanol and 70% ethanol. The antioxidant activity was measured by the DPPH (diphenyl-2-picrylhydrazyl) method and FRAP (Ferric Reduction Ability of Plasma) method. Based on the amount of polyphenol compounds as well as the antioxidant activity, the experiments showed that Soxhlet extraction with 70% methanol as solvent worked best for palm bunch waste and sugar cane pulp, resulted in about two times higher values for total phenolic content, flavonoid content and FRAP antioxidant activity as well as extract mass (yield) compared to the results from other extraction methods or solvents used in this experiment. The antioxidant activity of the extracts as measured by DPPH method seemed also to be promising, although the trend among solvent and extraction method was rather inconclusive.

## 1. Introduction

Indonesia is an agrarian country very rich in natural resources. Its climate and soil conditions are ideal for the cultivation of a large variety of plants that belong to important food staples. Examples of such plants include rice, palm oil, and sugarcane. Based on 2021 report from the Badan Pusat Statistik (BPS), sugar cane crop production reached 2,12 million tons in 2020. According to the Directorate General of Plantations, the Ministry of Agriculture and the Indonesian Palm Oil Entrepreneurs Association (GAPKI), the volume of palm oil crop production in Indonesia has continuously been growing and has already reached 51.63 million tons in 2020 (GAPKI, 2021). Increasing production, on the other hand, also leads to the accumulation of biowaste. It is not surprising that sugarcane pulp, and empty fruit bunches after palm oil harvest are building up in large quantities with every ton of food produced. Unfortunately, this biowaste is typically destroyed by burning in the fields, causing additional air pollution. Attempts have been made to transform biowaste into bioenergy or biofuel (Comelli et al., 2020; Ban et al., 2017) which,

however, require well-functioning logistics and a relatively low moisture content of the residues to be economically feasible. Another common use for agricultural waste is in animal husbandry. Sugar cane bagasse, however, does not qualify as animal feed though due to the low digestibility (Molavian et al., 2020).

Instead of disposing of agricultural waste it could, however, serve as a valuable resource for polyphenolic compounds with antioxidant properties (Tsouko et al., 2019). Phenolic acids, flavonoids, and anthocyanins are produced by plants as a protective mechanism to counteract biotic and abiotic factors. The positive effect of phenolic compounds on human health is well-known (Cory et al., 2018). For instance, regular green tea consumption has proven to enhance the cognitive function in elderly persons (Cory et al., 2018; Singh et al., 2015). In addition to antioxidant properties they may also show anti-inflammatory effects, both in inflammation mediated by reactive oxygen species (ROS) and induced by cytokines (Colombo et al., 2019; Zhang and Tsao, 2016). High-value applications of polyphenolic compounds include admixtures to functional foods (Lapornik, 2005) as natural antioxidants and additional

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nutrients, potential treatment for neurodegenerative diseases (Lantz et al., 2020), additions to blood pressure-lowering drugs (Fraga et al., 2021), for antimicrobial activity (Rather et al., 2021) or in combination with the functionalization of nanoparticle for various physiological effects (Alomary & Ansari et al., 2021; Sati et al., 2020). They can also be admixed to animal feed (Shi et al., 2005) or serve as nontoxic antioxidants in active food packaging (Vilela et al., 2018).

Polyphenols can be isolated from agricultural waste through an extraction process using organic solvents, such as methanol and ethanol as well as by polar solvents such as water or apolar solvents such as hexane (Shi et al., 2005). The solvents for the extraction process are selected based on the polarity of the target metabolite. Extraction with aqueous solvents is generally performed to obtain polar compounds while organic solvents aim to separate compounds of lower polarity and low molecular weight, such as saponins and flavonoids. In addition to the choice of the solvent, the method of extraction plays an important role. Several methods, such as maceration (Vianney et al., 2018), ultrasound assisted extraction (UAE) (Filho et al., 2021; Tsouko et al., 2019), and Soxhlet or reflux extraction (Shi et al., 2021; Li et al., 2013; Han and May, 2012) can also be employed. In general, extraction condition, such as temperature and time plays a role on the stability of the extracted compounds, yield, and efficiency of the processes (Lameirao et al., 2020). The above report mostly focused on optimizing the condition for a single method and one type of agrowaste.

In this research, based on request from our industrial partner, two types of agricultural waste products that amass in Indonesia, namely sugar cane bagasse and empty fruit bunches of oil palms, have been investigated for the total phenolic content and its antioxidant capacity, using data from the existing reports from other researchers above. The easiest, yet most efficient extraction process in each case was sought, since the target community/industries in Indonesia include also small and medium one with limited budget and knowledge of sophisticated extraction techniques and skills. Readily available and pretty cheap solvents and equipment were selected for the extraction. Thus, this project could lay the foundation of the attempt to not only reduce the amount of biowaste but also to obtain valuable raw materials for functional and nutritional additives.

## 2. Materials and methods

### 2.1. Materials and equipment

The waste of empty palm fruit bunches was obtained from plantations in Sampit, Central Kalimantan, Indonesia. Sugarcane bagasse was acquired from Surabaya, East Java, Indonesia. Folin-Ciocalteu reagent, sodium carbonate anhydrous, gallic acid, sodium nitrite, aluminium chloride, sodium hydroxide, catechin, DPPH (diphenyl-2-picrylhydrazyl), methanol, ethanol, sodium acetate anhydrous, acetic acid, TPTZ (2,4,6-tripyrindyl-s-triazine), hydrochloric acid, iron(III) chloride hexahydrate, and distilled water were used for the extraction and the analysis of the extracts. All chemicals were purchased from Merck (Indonesia), analytical grade and used without further purification.

For the determination of the polyphenolic and the flavonoid content of the samples, a UV-Vis spectrophotometer (Genesys 105 UV-Vis, Thermo Scientific, USA) and a microplate reader (FLUOstar Omega, BMG LabTech, USA) were used. Microplate reader was also employed for determination of antioxidant capacity with less sample volume.

### 2.2. Sample preparation

Samples for extraction were prepared by first thoroughly washing the agroindustrial waste (empty palm fruit bunches and sugarcane pulp) with distilled water, then cutting it into small pieces using a blender and drying it in an oven (Mettler GmbH, Germany) at 50 °C for three days or until it reached a constant weight. The fibers were sieved using a 40-mesh filter to yield a fibrous powder of uniform consistency.

### 2.3. Extraction methods

The goal of the project was to identify the most efficient solvent and the best, yet simplest extraction method for obtaining polyphenolic compounds from agricultural waste in considerable amounts so that the method could easily be upscaled for industrial purposes. If economically feasible processes can be developed, the extracted compounds might find many value-added applications as antioxidants in food, cosmetic and other industries. The success of the extraction will be measured by several common parameters related to the antioxidant capacity, i.e. Total Phenolic Content, Total Flavonoid Content and Antioxidant Activity.

Solvent extractions using three different methods were carried out with 3 different solvents, namely 70% aqueous ethanol, 70% aqueous methanol, and distilled water. The maceration method was basically chosen because it is simple and cheap. The other methods (Ultrasonic Assisted Extraction/UAE and Soxhlet Extraction) were carried out to expect less extraction time needed since the power used in UAE technique and higher temperature in Soxhlet Extraction may help to break the plant cell wall of empty palm fruit bunches and sugar cane pulp.

The maceration process was carried out by following the protocol of Vianney et al. (2018), in which 2.5 g of sample were immersed in 150 mL solvent and stirred for 72 h at 40 °C in a waterbath. Thereafter the solvent was evaporated with a rotary evaporator (Heidolph, Germany) and the extract was redissolved in the same solvent to 50 mL for analytical purposes (Lapornik et al., 2005).

UAE was carried out for 30 min at room temperature using an ultrasonicator (Branson Ultrasonic 1510, USA) with a frequency 40 kHz (Park et al., 2006). For this method, 2.5 g of sample were immersed in 150 mL solvent and after 30 min the solvent was removed by a rotary evaporator to determine the obtained extract mass. The extract was redissolved in the same solvent to 50 mL.

Soxhlet extraction was performed using 5 g of extract with 300 mL of solvent at a temperature of 60 °C for 2 h. After 2h the solvent was removed by a rotary evaporator to measure the extract mass and the extract was redissolved in the same solvent to 50 mL.

### 2.4. Determination of total phenolic content

Total phenolic content was measured using Folin-Ciocalteu method. The working protocol was based on Vianney et al. (2018) with slight modification, namely 0.1 mL extract was mixed with 0.2 mL of Folin-Ciocalteu reagent, 2 mL distilled water, and 1 mL of 15% anhydrous sodium carbonate (w/v). The solution was then stored in a dark room for 1 h and the absorbance determined with a UV-Vis spectrophotometer at a wavelength of 765 nm, using gallic acid as standard. Blank solutions were prepared by the same method, replacing the sample solution with distilled water. Three replications of the test were performed. The total phenolic content was calculated by Eq. (1)

$$\text{Total phenolic content} = \frac{\text{Gallic acid equivalent (GAE)}(\text{mg})}{\text{g dry mass sample}} \quad (1)$$

### 2.5. Total flavonoid content

Total flavonoid content assay was conducted based on the research of Benariba et al. (2013) with modifications, namely 0.1 mL extract (dissolved in the respective solvent) was mixed with 0.15 mL 15% aqueous NaNO<sub>2</sub> and 0.15 mL 10% aqueous AlCl<sub>3</sub>. The solution was allowed to stand for 6 min at room temperature, then 2 mL 1M NaOH were added and the solution diluted with distilled water to 5 mL. It was then incubated for 15 min at room temperature. The absorbance of the solution was measured with a UV-Vis spectrophotometer at a wavelength of 510 nm using catechin as standard compound. Blank solutions were made by the same method, replacing the solvent with distilled water. Each test was replicated 3 times. The total flavonoid content was calculated using Eq. (2) and expressed as catechin equivalents (CE)



$$\text{Total flavonoid content} = \frac{\text{Catechin equivalent (CE)}(\text{mg})}{\text{g dry mass sample}} \quad (2)$$

## 2.6. Antioxidant activity

The antioxidant effect of the polyphenol extracts was measured using two different methods, namely the DPPH and FRAP. This was necessary since the DPPH method may not be able to accurately determine antioxidant properties of hydrophilic compounds due to solubility issues with DPPH. With FRAP, on the other hand, hydrophilic compounds can be accounted for (Ulewicz-Magulska and Wesolowski, 2019).

## 2.7. DPPH method

Based on Abozed et al. (2014) the DPPH test was conducted by mixing 90  $\mu\text{L}$  of 0.15 mM DPPH (diphenyl-2-picrylhydrazyl) with 30  $\mu\text{L}$  of test extract. The solution mixture was left in a dark room at room temperature for 30 min; subsequently its absorbance was measured at a wavelength of 515 nm. The control solution was made by mixing 4.9 mL of DPPH reagent with 0.1 mL of methanol and after 30 min in dark room at room temperature, the absorbance was measured at a wavelength of 515 nm. The antioxidant property of the sample was expressed as radical scavenging capacity (% inhibition, Eq. (3)) and as gallic acid equivalents (GAE, Eq. (4)).

$$\% \text{ Inhibition} = \frac{\text{Control abs} - \text{sample abs}}{\text{Control abs}} \times 100\% \quad (3)$$

$$\text{Antioxidant activity} = \frac{\text{Gallic acid equivalent (GAE)}(\mu\text{mol})}{\text{g dry mass sample}} \quad (4)$$

## 2.8. Ferric Reduction Ability of Plasma (FRAP)

Based on the procedure described by Benzie and Strain (1996), a sodium acetate buffer solution of pH 3.6 was prepared. 270 mg of TPTZ (2,4,6-tripyridyl-s-triazine) were dissolved in 50 mL 40 mM HCL. A 20 mM  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$  solution was prepared with distilled water. The FRAP reagent was made by mixing 25 mL of the acetate buffer, 2.5 mL of 10 mM TPTZ, and 2.5 mL of 20 mM  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$  solution. The volume was adjusted to 100 mL using distilled water.

For the assay, 60  $\mu\text{L}$  sample were mixed with the FRAP reagent at a ratio of 1:1. The absorbance was measured at a wavelength of 593 nm. A standard solution was prepared using gallic acid and treated the same as a sample solution. Blank solutions were made by the same method with distilled water. All assays were repeated three times. The antioxidant activity was determined with Eq. (5) and expressed as gallic acid equivalents (GAE).

$$\text{Antioxidant activity} = \frac{\text{Gallic acid equivalent (GAE)}(\mu\text{mol})}{100 \text{ g dry mass sample}} \quad (5)$$

## 2.9. Statistical analysis

A randomized method was used to design the experiments where the first factor taken is the solvent of extraction, followed by the extraction method itself. All the experiments conducted in this study were repeated three times and the data reported are average values with standard deviations. All data in this study were analyzed with the Shapiro-Wilk normality test, One-Way ANOVA and a significance test with a value of  $\alpha = 0.05$ . If the data are not normally distributed, a one-way ANOVA analysis cannot be applied. For non-normal data, the Kruskal-Wallis method was utilized, followed by a signification test using the Mann-Whitney test with a value of  $\alpha = 0.1$ . Minitab 18 software was employed to conduct the analysis.

## 3. Results and discussion

### 3.1. Empty palm fruit bunches as raw material

Empty palm fruit bunches are the major by-product of the palm oil production. Besides cellulose, hemicellulose and lignin, it also contains polyphenolic compounds that can be extracted. Table 1 lists the results of maceration with three solvents. Maceration is the simplest extraction method to perform, though also the most time consuming one (Jeyaraj et al., 2021). In the Table 1, it was shown that there was a significant difference in term of the phenolics concentration in the extracts yielded from different methods and solvents.

Distilled water and 70% methanol provided best total phenolic content, followed by ethanol. Although the total phenolic concentration results obtained here were still somewhat lower compared to those reported by Tsouko et al. (2019), they paralleled those reported by Ulewicz-Magulska and Wesolowski (2019). There it is stated that the use of 80% methanol and distilled water as solvents did not make a significant difference for the total concentration of phenolics in the extracts.

In the case of flavonoids, 70% methanol yielded the highest amount from the extract, but overall, the obtained data did not differ markedly. It would be expected that the total concentration of flavonoids in the extracts is lower than that of the phenolics since they are only a sub-group thereof. However, the standard for phenolics is gallic acid, while it is catechin for flavonoids. Thus, the two methods are not directly comparable. As a general rule, the more phenolics can be extracted, the more potent the antioxidant qualities of the extract should be. From Table 1 it is shown that 70% methanol as the solvent gave the highest result for the antioxidant activity determined by DPPH (%inhibition) and FRAP ( $\mu\text{mol}$  GAE/g sample), while water gave the lowest value of antioxidant activity determined by both methods. This could mean, that water extracted much more compounds (as indicated also by the yield obtained) that contributed false positive result for total phenolic determination. Moreover, some of the % inhibition values of DPPH obtained from our experiments were more than 85% present. This could indicate a plateau of the reaction and thus, conclusion should not be taken solely based on these DPPH % inhibition values, but also by looking at the other parameters.

**Table 1.** Total phenolic, flavonoid content, and antioxidant activity obtained after extraction of empty palm fruit bunches with different solvents (extraction method: maceration).

Extractives	70% Methanol	70% Ethanol	Dist. Water
Total Phenolic Content (mg GAE g <sup>-1</sup> sample)	0.86 <sup>a</sup> ± 0.123	0.47 <sup>b</sup> ± 0.056	1.15 <sup>a</sup> ± 0.195
Total Flavonoid Content (mg CE g <sup>-1</sup> sample)	1.92 <sup>a</sup> ± 0.379	1.03 <sup>a</sup> ± 0.736	1.64 <sup>a</sup> ± 0.189
Antioxidant Activity DPPH (% Inhibition)	89.83 <sup>a</sup> ± 3.420	88.93 <sup>ab</sup> ± 0.990	82.66 <sup>b</sup> ± 3.120
Antioxidant Activity DPPH ( $\mu\text{mol}$ GAE g <sup>-1</sup> sample)	4.045 <sup>a</sup> ± 0.424	3.828 <sup>a</sup> ± 0.210	3.117 <sup>a</sup> ± 0.879
Antioxidant Activity FRAP ( $\mu\text{mol}$ GAE g <sup>-1</sup> sample)	19.02 <sup>a</sup> ± 0.717	12.54 <sup>b</sup> ± 0.415	10.98 <sup>b</sup> ± 3.830
Extract Yield (% w/w)	8.01 <sup>a</sup> ± 3.402	7.37 <sup>a</sup> ± 3.173	16.93 <sup>a</sup> ± 6.180

Note: All data in Table 1 are the average value of 3 independent experiments with standard deviations; letters in rows indicate a significant difference based on the results of the ANOVA One-Way test with a confidence level of 95%.



**Table 2.** Total phenolic, flavonoids content, and antioxidant activity results using different extraction methods (solvent: 70% methanol).

Method	UAE	Soxhlet	Maceration
Total Phenolic Content (mg GAE g <sup>-1</sup> sample)	0.60 <sup>b</sup> ± 0.057	0.80 <sup>a</sup> ± 0.052	0.71 <sup>ab</sup> ± 0.022
Total Flavonoid Content (mg CE g <sup>-1</sup> sample)	2.98 <sup>b</sup> ± 0.575	3.97 <sup>a</sup> ± 0.328	3.57 <sup>ab</sup> ± 0.180
Antioxidant Activity DPPH (% Inhibition)	67.03 <sup>c</sup> ± 0.811	76.44 <sup>a</sup> ± 1.087	71.84 <sup>b</sup> ± 0.862
Antioxidant Activity DPPH (μmol GAE g <sup>-1</sup> sample)	2.04 <sup>c</sup> ± 0.211	4.48 <sup>a</sup> ± 0.283	3.29 <sup>b</sup> ± 0.224
Antioxidant Activity FRAP (μmol GAE g <sup>-1</sup> sample)	9.48 <sup>b</sup> ± 1.188	18.48 <sup>a</sup> ± 3.960	13.30 <sup>ab</sup> ± 1.672
Yield (% w/w)	8.47 <sup>a</sup> ± 2.083	15.34 <sup>a</sup> ± 3.307	5.72 <sup>ab</sup> ± 1.017

Note: All data in Table 2 are the average values of 3 independent samples with standard deviations; letters in rows indicate a significant difference based on the results of the ANOVA One-Way test with a confidence level of 95%.

We then also investigated different extraction methods (Maceration, Soxhlet, and Ultrasound Assisted Extraction/UAE) for 70% methanol as solvent. In Table 2, the results are depicted which were obtained with 2.5 g sample in 150 mL solvent. It can be seen that Soxhlet extraction tended to give slightly higher value for total phenolic and total flavonoid in comparison to the other methods. Also, Soxhlet Extraction with 70% methanol as solvent provided extract with the best antioxidant activity in comparison to other methods, as indicated by the DPPH (%inhibition) and FRAP value (μmol GAE/g sample).

It is possible that the elevated temperature during this extraction process increased the solubility of the metabolites (Nile et al., 2017). In general, Soxhlet extraction yielded the highest antioxidant activity compared to the other two methods. These results are in line with those of Khalil et al. (2018) and Nile et al. (2017), where the higher total phenolics resulted in higher antioxidant activity. However, compared to other studies found in literature, the data for empty fruit bunches of oil palms were still lower than for extracts of sugarcane pulp reported below.

The UAE method yielded the lowest value for all parameters. It is possible that the applied ultrasonic procedure was too mild and thus less effective for the rather dense biomass substrates to provide the needed turbulence and contact between solvent and extract (Wang and Weller, 2006). It is still necessary to research further the optimum power and duration of ultrasonication needed for the sufficient extraction.

### 3.2. Sugarcane pulp as resource for antioxidants

Waste from sugarcane production generally contains approximately 45–60% cellulose, 25% hemicellulose, 20–25% lignin and it is commonly used as a low-energy fuel or as fibrous reinforcement in composite materials (Hajiha and Sain, 2015). However, due to its low cost and high availability, sugarcane pulp can also serve as a worthwhile resource for phenolic compounds and its analysis of potential phenolic and flavone compounds as well as the chemical structures contained in sugarcane has been reported in Singh et al. (2015).

In Table 3 the results for maceration with alcohols and distilled water of sugarcane samples are displayed. The overall yield of extract mass was higher for sugarcane compared to extracts of empty palm fruit bunches (see Table 1 for comparison).

No major differentiation, however, could be made between methanol and ethanol on total flavonoid content while there is difference on total phenolic content in the extracts obtained by three different solvents. Apparently, distilled water gave the lowest amount on both total phenolic and total flavonoid content.

With sugarcane, the highest total phenolics content could be extracted with 70% ethanol. This finding is rather similar with those of Venkatesan et al. (2019) on pine plant extraction. It seems that the phenolics in the sugarcane extract, like ferulic acid and coumaric acid have a similar polarity as 70% ethanol and thus go into solution easily under these experimental conditions (Zhao et al., 2015).

In Table 3, we can see that some of the % inhibition values of DPPH obtained from our experiments were more than 85% present. This could indicate a plateau of the reaction and thus, conclusion should not be taken solely based on these DPPH % inhibition values, but also by looking at the other parameters. While the values of antioxidant activity resulted from DPPH assay are rather similar for all extracts, the highest antioxidant activity was shown by the extract from 70% methanol as measured with FRAP method. This data trend somewhat aligns well the flavonoid content data using catechin as standard compound, which also in concordance with the work of Vianney et al. (2018) and Vijayalaxmi et al. (2015), reporting that methanol seems to be well-suited as solvent to yield flavonoids, while ethanol and water dissolved less flavonoids. There is a possibility that the antioxidant activity of sugarcane methanol extract is mostly contributed from the extracted flavonoid compounds.

Table 4 presents a comparison of extraction methods for sugarcane pulp by means of 70% methanol. It is obvious that using Soxhlet method, the highest yield could be obtained, while UAE gave the least extract yield. As also observed with empty fruit bunches of palm oil, Soxhlet extraction provided the highest amount of phenolics and flavonoids.

While the data of DPPH assay is rather inconclusive, we can see in Table 4 that the FRAP assay data is in line with value of phenolic and flavonoid content. As has been expected, the extract from Soxhlet extraction gave the highest antioxidant activity as measured by FRAP method (μmol GAE g<sup>-1</sup> sample).

Although some researchers like Juttuporn et al. (2017) proposed UAE as the potential best technique for industrial application for the sake of shorter extraction time, this report rather complements other reports that

**Table 3.** Total phenolic, flavonoids, and antioxidant activity profile after extraction of sugarcane pulp as raw material with different solvents (extraction method: maceration).

Extractive	70% Methanol	70% Ethanol	Dist. Water
Total Phenolic Content (mg GAE g <sup>-1</sup> sample)	1.35 <sup>b</sup> ± 0.096	1.67 <sup>a</sup> ± 0.097	0.8 <sup>c</sup> ± 0.037
Total Flavonoid Content (mg CE g <sup>-1</sup> sample)	3.29 <sup>a</sup> ± 1.091	1.95 <sup>ab</sup> ± 0.605	0.50 <sup>b</sup> ± 0.236
Antioxidant Activity DPPH (% Inhibition)	85.67 <sup>a</sup> ± 1.080	86.02 <sup>a</sup> ± 0.911	78.45 <sup>b</sup> ± 0.632
Antioxidant Activity DPPH (μmol GAE g <sup>-1</sup> sample)	1.67 <sup>a</sup> ± 0.116	1.82 <sup>a</sup> ± 0.123	1.12 <sup>b</sup> ± 0.477
Antioxidant Activity FRAP (μmol GAE g <sup>-1</sup> sample)	30.81 <sup>a</sup> ± 1.950	15.45 <sup>c</sup> ± 1.080	25.09 <sup>b</sup> ± 1.189
Yield (% w/w)	12.05 <sup>a</sup> ± 2.102	10.00 <sup>a</sup> ± 3.128	19.85 <sup>a</sup> ± 3.275

Note: The data in Table 3 are the average value of three independent extractions with standard deviation; letters in rows indicate a significant difference based on the results of the ANOVA One-Way test with a confidence level of 95%.



**Table 4.** Impact of the extraction method on total phenolic and flavonoids concentration as well as antioxidant activity for sugarcane pulp (solvent: 70% methanol).

Method	UAE	Soxhlet	Maceration
Total Phenolic Content (mg GAE g <sup>-1</sup> sample)	0.30 <sup>c</sup> ± 0.007	0.96 <sup>a</sup> ± 0.003	0.41 <sup>b</sup> ± 0.008
Total Flavonoid Content (mg CE g <sup>-1</sup> sample)	2.28 <sup>c</sup> ± 0.104	5.48 <sup>a</sup> ± 0.202	4.47 <sup>b</sup> ± 0.180
Antioxidant Activity DPPH (% Inhibition)	84.29 <sup>a</sup> ± 0.611	71.03 <sup>c</sup> ± 0.316	74.76 <sup>b</sup> ± 0.593
Antioxidant Activity DPPH (μmol GAE g <sup>-1</sup> sample)	1.60 <sup>a</sup> ± 0.019	0.75 <sup>c</sup> ± 0.103	0.93 <sup>b</sup> ± 0.021
Antioxidant Activity FRAP (μmol GAE g <sup>-1</sup> sample)	11.69 <sup>c</sup> ± 1.471	36.20 <sup>a</sup> ± 0.849	21.49 <sup>b</sup> ± 1.531
Yield (% w/w)	8.17 <sup>b</sup> ± 2.036	19.00 <sup>a</sup> ± 2.271	9.77 <sup>b</sup> ± 3.073

Note: The data in Table 4 are the average values with standard deviations of three independent experiments; letters in rows indicate a significant difference based on the results of the ANOVA One-Way test with a confidence level of 95%.

still indicate the older Soxhlet extraction as the method with the highest extraction yield. It seems that the heating process in Soxhlet extraction provided a greater disruption of the plant cell wall, a greater penetration of the solvent, and a greater release of extractable compounds. There are of course still possibilities to optimize the UAE condition (power, time, solvent choice) to achieve higher extraction result.

#### 4. Conclusion

Comparative research was performed to investigate feasible extraction methods of fibrous waste from agriculture, i.e. empty fruit bunches from palm oil production and sugarcane pulp. Those agricultural waste are highly available and plentiful in Indonesia and are currently destroyed by burning, causing air pollution. Methods were studied that would allow extraction of the polyphenols in a simple and economical manner, so it may feasibly be adopted by the corresponding potential small to medium enterprise/industry.

The best extraction results for palm bunches and sugarcane pulp were obtained by the Soxhlet method at 60 °C for 2 h with 70% methanol as the solvent, resulted in about two times higher values for total phenolic content, flavonoid content and FRAP antioxidant activity as well as extract mass (yield) in comparison to maceration and Ultrasonic Assisted Extraction (UAE) methods with the conditions as applied in this work. In future research, extraction conditions still need to be further optimized in terms of temperature and duration of extraction, perhaps also concerning the sample mass to solvent volume ratio.

#### Declarations

#### Author contribution statement

Leonardo Satriono Putra: Performed the experiments; Wrote the paper.

Johan Sukweenadhi: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Clairine Nathania, Enrico Setiawan Wibowo: Performed the experiments; Analyzed and interpreted the data.

Gisela Buschle-Diller: Analyzed and interpreted the data; Wrote the paper.

Maria Goretti Marianti Purwanto: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

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#### Data availability statement

Data included in article/supplementary material/referenced in article.

#### Declaration of interests statement

The authors declare no conflict of interest.

#### Additional information

No additional information is available for this paper.

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# Heliyon



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## Heliyon editors

*Heliyon* is actively building individual sections that are managed by respected researchers and experts in the field. These dedicated and experienced section editors and their teams of associate editors, supported by our in-house editorial team, are responsible for managing the peer review process for all submitted manuscripts within their subject sections. These dedicated sections allow us to tailor each author's experience to the needs and standards they have come to expect within their respective fields.

*Heliyon* has recently created a collection of [publications from our editorial board](#), which you may be interested in reading.

### Agriculture

Meet the full editorial team for *Heliyon Agriculture*.



**Dr. Athanasios Damialis**

Dr. Athanasios Damialis is a multi-disciplinary scientist working for more than 20 years on the fields of plant and fungal ecology, environmental sciences, biometeorology, climate change and environmental health. His particular focus lies on the reproductive biology of plants (flowering phenology, atmospheric circulation of airborne pollen) and on endophytic fungi. He uses an inter-disciplinary research approach with environment-environment interactions and human-environment interactions. This includes mainly those interactions including, but not limited to, the detection of bio-climatic indicators and spatiotemporal patterns of plant, forest and agricultural habitats and ecosystems, in relation to ongoing and simulated climate change. His research goal is to comprehend the responsive ability of organisms under stress conditions, ultimately, attempting to promote sustainable growth and environmental quality.

### Arts and humanities

Meet the editorial team for *Heliyon Arts and humanities*.

### Biochemistry, molecular biology and cell biology

Meet the full editorial team for *Heliyon Biochemistry, molecular biology and cell biology*.



**Prof. Nicola Zambrano**

Nicola Zambrano is professor of Molecular Biology at the University of Naples Federico II, and group leader at CEINGE Advanced Biotechnologies, Naples, Italy. He holds a M.Sc. degree in biological sciences and a Ph.D. in biotechnologies, acquired within a joint doctoral program from the Universities of L'Aquila and Naples, Italy. He was a visiting fellow at National Cancer Institute, NIH in Bethesda from 1991 to 1994, and visiting scientist at EMBL in Heidelberg, Germany in 1997. His academic career at the Federico II University in Naples started with an assistant professor position in biochemistry (1996), before being enrolled as an associate professor (2002) and then, as a full professor in molecular biology (2010).



**Prof. Jinrong Min**

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Professor Jinrong Min received his Ph.D. degree in physics from the Institute of Physics, Chinese Academy of Sciences in China, and carried out his post-doctoral training in chromatin structural biology at the Cold Spring Harbor Laboratory, USA. He is currently the principal investigator of the Chromatin Structural Biology Group at the Structural Genomics Consortium (SGC), University of Toronto, and an associate professor in the Department of Physiology at the University of Toronto.

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## Biology

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## Business and economics

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**Dr. Larisa Yarovaya**

Doctor Larisa Yarovaya received her doctorate in finance from Northumbria University in England. Currently, she is a lecturer in finance, Programme Director BSc Finance, and deputy head of Centre for Digital Finance at the Southampton Business School, University of Southampton.

Dr. Yarovaya is a researcher in the fields of international finance, digital finance, financial integration, Islamic finance, energy economics, information transmission, and international business. She has published her research in peer-reviewed academic journals and is an associate editor of the *International Review of Financial Analysis*, *Journal of International Financial Markets Institutions and Money*, *Heliyon*, and *Data-in-Brief*.



**Assoc. Prof. Pavlos Delias**

Pavlos Delias is a tenured faculty member at the [International Hellenic University](#), Department of Accounting and Finance. He holds a jointly supervised PhD from both [Technical University of Crete](#) and [University Paris Dauphine](#), under a cotutelle agreement.

Pavlos Delias has been invited as a visiting professor in several universities (national as well as international). He has contributed to numerous research projects, focusing on applying the principles of business analytics and operational research to decision support systems design and use. He is also a member of the coordination board for the EURO working group on decision support systems. His research interests are in the areas of business process analytics, business analytics and operational research, and multiple criteria analysis.



**Assoc. Prof. Eugene Ezebilo, PhD**

Eugene Ezebilo is an Associate Professor of Economics. He received his PhD in Economics from Swedish University of Agricultural Sciences, Sweden. He is currently a Deputy Director for Research at the National Research Institute, Port Moresby in Papua New Guinea. He is a guest lecturer at University of Papua New Guinea where he teaches two courses in the Master of Economics and Public Policy program. In the past ten years, Eugene's research has focused primarily on the economic value of ecosystem goods and services, land use planning, affordable housing and economic development. His academic career started at Swedish University of Agricultural Sciences as a Post-Doctoral Researcher in Environmental and Natural Resource Economics, followed by an Assistant Professor in Economics and Planning from the same university, where he later became an Associate Professor of Economics. His research interests are in environmental and resource economics, housing economics and policy, land use planning and economic development.

## Cancer Research

Meet the full editorial team for [Heliyon Cancer Research](#).



**Prof. Graham Pawelec**

Graham Pawelec received an MA in Natural Sciences and a PhD in Transplantation Immunology from the University of Cambridge, UK. He is currently Professor of Experimental Immunology in the Department of Immunology, University of Tübingen, Tübingen, Germany. He is a Visiting Professor at Nottingham Trent University, UK and at King's College London, UK, holds an Honorary Chair at Manchester University, UK. He is a member of the Cancer Solutions Program at the Health Sciences North Research Institute of Canada, Sudbury, Ontario, Canada. He is currently Co-Editor-in-Chief of "Immunity and Aging". Graham's research interests are centred on alterations to immunity, especially T cell-mediated immunity, in ageing and cancer in man, and the influence these have on the outcome of vaccination and immunomodulatory antibody therapies. The impact of polypathogenicity (including multiple infections, cancer, Alzheimer's, diabetes, autoimmunity) as well as stress (psychological, nutritional) on immune signatures reflecting individual immune status is of particular interest in the clinical context.

## Chemical Engineering

Meet the full editorial team for [Heliyon Chemical Engineering](#).



**Prof. Bart Van der Bruggen**

Bart Van der Bruggen received his PhD in chemical engineering from KU Leuven in 2000. He currently works as full professor at KU Leuven (Belgium) and extraordinary professor at Tshwane University of Technology (South Africa). He has vast experience as an editor for various journals and is also very active author and reviewer, with over 600 publications, cited more than 25,000 times. His expertise is in separation processes in classical and non-classical chemical engineering applications, with a focus on membrane science and technology.

## Chemistry

Meet the full editorial team for [Heliyon Chemistry](#).



**Dr. Francesco Epifano**

Prof. Epifano obtained his degree in medicinal chemistry and pharmaceutical technology in 1993 from the University of Perugia, Italy. In 1998, he obtained his Ph.D. in agricultural entomology at the Faculty of Agricultural Sciences of the University of Perugia. Currently, he is an associate professor of medicinal chemistry at the Department of Pharmacy of the University Gabriele D'Annunzio of Chieti-Pescara. His recent work is concerned with synthesis and pharmacological properties of secondary metabolites from plants, fungi, and bacteria. Dr. Epifano was the recipient of the 2010 IADR / Glaxo Smith Kline Innovation in Oral Care Award as the co-investigator of the project entitled "Therapeutic potential of Citrus auraptene for periodontal disease", the 2012 Apivita Award for Phytochemistry, and the 2017 Pierre Fabre – Phytochemical Society of Europe Innovation Award.

## Clinical research

Meet the full editorial team for [Heliyon Clinical research](#).



**Dr. Carolyn Mackintosh-Franklin**

Dr. Carolyn Mackintosh-Franklin has had an extensive career in both clinical practice and higher education working at the University of Bradford, University of Liverpool, University of Hull and currently working at the University of Manchester. She received her first degree from the University of Newcastle Upon Tyne, her MSc from the University of Manchester and doctorate from the University of Bradford. She is also a registered nurse specializing in the assessment and management of acute and chronic pain. Her research interests are broad ranging; encompassing work on health care professionals' attitudes towards those in pain, aspects of pain assessment and management, and pedagogic research into learning needs of mature students, with a range of highly cited publications and conference



presentations in these areas.



**Assoc. Prof. Giuseppe Musumeci**

Giuseppe Musumeci received a BS, MS and PhD in Human Movement and Sport Sciences from the University of Catania, Italy. Currently, he works as a Professor of Sports Sciences at the Department of Biomedical and Biotechnological Sciences, School of Medicine, University of Catania, Italy. He is also an Adjunct Professor at the Temple University's College of Science and Technology, Philadelphia, USA and at the Faculty of Sport Sciences, Fujian Normal University, Fuzhou, China. Prof. Musumeci is the Director of the Research Center on Motor Activities (CRAM), the Director of School of Posturology and Physical Exercise Sciences, the Dean of the Human Movement Sciences Faculty and the Head of the Movement Innovation PosturaLab at the University of Catania. He is currently Editor-in-Chief of "Journal of Functional Morphology and Kinesiology". Musumeci's research interests are centered on morphological, molecular, biochemical and clinical aspects of osteoarthritis and musculoskeletal disorders and the relative effects of diet, ageing and physical activity. Other research topics of interest are tissue engineering and mechanobiology related to the musculoskeletal system in the clinical context.

## Computer science

Meet the full editorial team for [Heliyon Computer science](#).



**Assoc. Prof. Jonathan Chan**

Assoc. Prof. Jonathan H. Chan is an associate professor of computer science and a co-founder of D-Lab at the School of Information Technology, King Mongkut's University of Technology Thonburi, Thailand. Jonathan holds a Ph.D. from the University of Toronto, where he has also served as a visiting professor. In addition to his role as the section editor of *Heliyon Computer science*, Dr. Chan is an action editor of *Neural Networks*, and a member of the editorial boards of *International Journal of Machine Intelligence and Sensory Signal Processing*, *International Journal of Swarm Intelligence*, and *Proceedings in Adaptation, Learning and Optimization*.

Dr. Chan is a founding member and a current VP of the IEEE-CIS Thailand Chapter, and a senior member of IEEE, ACM, and INNS, a member of the Professional Engineers of Ontario (PEO), and a governing board member of APNNS. He also holds an NVIDIA Deep Learning Institute (DLI) University Ambassadorship and is a certified DLI instructor. His research interests include intelligent systems, biomedical informatics, and data science and machine learning in general.

## Dentistry

Meet the full editorial team for [Heliyon Dentistry](#).



**Gaetano Isola, PhD**

Dr. Gaetano Isola qualified in Dentistry at the University of Messina, Italy and obtained his PhD in "Physiopathology of the Stomatognathic Apparatus and Dental Materials" at the University of Turin, Italy. He is a visiting research fellow at the Laboratory of the Study of Calcified Tissues and Biomaterials at the Department of Periodontology, Université de Montréal, Canada. Dr. Isola did an advanced course in periodontology at the University of Ferrara and a 3-year certificate in oral surgery at the University of Naples "Federico II." He is a visiting Professor at the Department of Periodontology, University of North Carolina at Chapel Hill, USA and at the Department of Oral Surgery, University of Granada, Spain. He is also a visiting researcher at the Department of Implantology and Oral Surgery, University of Bern, Switzerland, and the Department of Periodontology, Eastman Dental Institute, London.

Dr. Isola is an active member of the Italian Society of Oral Surgery (SIdCO) and of the International Piezoelectric Surgery Academy (IPA). He serves on the board of the International Association of Dental Research (IADR) and is a member of the Italian Society of Periodontology (SIdP), as well as an active member of the International IADR Constitution Committee of the International Association of Dental Research (IADR) (2016–2019 and 2019–2022).

His main research interests focus on the clinical, biological, and pharmacological aspects of periodontitis, and the relationship between oral health and systemic health and the pre-neoplastic disorders.

## Earth science

Meet the full editorial team for [Heliyon Earth science](#).



**Prof. Andrew S. Hursthouse**

Professor Hursthouse is a professor of environmental geochemistry at the University of the West of Scotland (UWS) and holds a Ph.D. in environmental radioactivity from University of Glasgow and a B.Sc. degree in geochemistry from University of Reading. He holds a 100 talent high-end expert fellowship at Hunan University of Science & Technology, Xiangtan, PRC. He has editorial roles in several earth and environmental science journals and has worked in academic and industrial research environments.

Professor Hursthouse's areas of interest and expertise are in earth process interactions and the environmental geochemistry of metallic elements, resource exploitation and implications for human health, and this approach also applied to environmental pollution, industrial processes, economic development and society; remediation and treatment of chemical pollution; chemical and environmental hazards, waste and environmental management and regulation.

## Education

Meet the full editorial team for [Heliyon Education](#).



**Prof. David González-Gómez**

*Heliyon Education* is led by Section Editor David González-Gómez, Ph.D. Dr. González-Gómez is a Professor in the Department of Science and Mathematics Education and the Dean of the Teaching Trainer School at the University of Extremadura (Spain). Dr. González-Gómez is known internationally for work in science education; science, technology, engineering, and mathematics (STEM); active learning methodologies for teaching science; affective domain in the science learning process; education for the sustainability; SDGs. Currently, he is an advisory council of the Science, Technology, and Innovation of Extremadura government in Spain.

## Energy

Meet the full editorial team for [Heliyon Energy](#).



**Dr. Socrates Kaplanis**

Prof. Socrates Kaplanis obtained his degree in physics from University Thessaloniki, a MSc in nuclear reactors from Aston University, and a PhD in radiation detection and modelling from the University Patra. He has held academic positions including professor of renewable energy systems at the Technological Educational Institute of Patra, head of the renewable energy systems laboratory, honorary professor and doctor honoris causa at the Transylvania University in Brasov, and as a visiting professor at the University of Applied Sciences in Aachen, Germany.

Prof. Kaplanis has a research background in solar radiation, prediction modelling, zero and intelligent energy buildings, PV systems engineering, solar thermal engineering, and PV based hybrid systems. He has held various posts, including president of the Technological Educational Institute of Patra, president of the Technological Educational Institute of Western Greece, and vice-president and President of the European Institutions in Higher Education (EURASHE).

## Engineering

Meet the full editorial team for [Heliyon Engineering](#).



**Prof. Andrea Francesco Morabito**

Professor Andrea Francesco Morabito received his Ph.D. in computer, biomedical, and telecommunications engineering from the University of Reggio Calabria, Italy, where he has also served as an assistant professor in electromagnetic fields since 2010. His



research work is mainly focused on models and effective strategies for the solution of inverse problems, in particular, antenna synthesis, phase retrieval, and electromagnetic inverse scattering.



**Prof. Mohammad Mehdi Rashidi**

Professor Mohammad Mehdi Rashidi received his Ph.D. in mechanical engineering from Tarbiat Modares University, Iran. He is currently a professor of mechanical engineering at Tongji University in Shanghai, China, and previously taught at Bu-Ali University in Iran. Prof. Rashidi was named a 2018 highly cited researcher by Clarivate Analytics.

## Environment

Meet the full editorial team for [Heliyon Environment](#).



**Prof. Frederic Coulon**

Professor Frederic Coulon holds a chair in Environmental Chemistry & Microbiology at Cranfield University, UK. In addition to his position as section editor for *Heliyon Environment*, Prof. Coulon is an associate editor for *Environment International* and *Science of the Total Environment*. His professional interests include: soil and water chemistry; fate and transport of chemicals in surface and subsurface waters; water and wastewater treatment; soil and sediment treatment; hazardous waste site remediation; energy and environment; population and environment; and public communication of environmental science and engineering. His research achievements address international priorities under the umbrella of the Water-Soil-Waste nexus across sectors and scales. His work is premised on the understanding that environmental resources are inextricably intertwined and therefore there is a need of advancing a nexus approach to enable integrated and sustainable management of water, soil and waste systems.



**Prof. Christian Sonne**

Professor Christian Sonne, DVM, PhD, DScVetMed, Dipl. ECZM-EBVS, holds a professorship in veterinary ecotoxicology and wildlife medicine at Aarhus University, Denmark. In addition to his position as section editor for *Heliyon Environment*, Prof. Sonne serves as special issues editor for *Environmental Pollution*. Since 1997, Prof. Sonne has specialized in the cross-field of biological effects from exposure to environmental chemicals, diseases and climate change, giving him a unique insight and profile working with a broad range of animals including predatory mammals, raptorial birds, sea birds, fish and humans. He has a broad insight and interest in internal and reproductive organs (histopathology, size, and morphology), skeletal system (bone density and morphology using e.g. DXA scanning), immune system (intra dermal testing of lymphocyte functioning, immune globulin production and cytokine and APP expressions), endocrine system (steroid and peptide hormones), PBPK modelling, blood biochemistry and infectious diseases (zoonosis). Prof. Sonne uses his global network to obtain interdisciplinary research results. Since 2015, he has applied his in-depth knowledge and understanding of biological processes to also include specific un-solved wildlife issues in Denmark (eider duck population declines) and health of raptors. Recently his innovative approaches have led to the first interactions with private industry focusing on natural resources developments and translational medicine within insulation, osteoporosis and metabolic syndrome. Prof. Sonne also specializes in surgical field implantations of intra-coelomic (abdominally) and subcutaneously satellite transmitters (PTTs) in various sea bird species and immobilization of deer spp.

## Food science and nutrition

Meet the full editorial team for [Heliyon Food science and nutrition](#).



**Dr. Lilian Mariutti**

Dr. Lilian R. B. Mariutti received her master and doctorate degrees in food science from the School of Food Engineering - University of Campinas, Brazil, where she currently has a position as assistant professor. She was a researcher fellow in the Laboratory of Veterinary Drug Residues of the Brazilian Ministry of Agriculture, Livestock and Food Supply. Her research focuses on the identification and bioaccessibility of bioactive compounds and lipids and design of food ingredients from non-conventional sources.

## Genetics

Meet the full editorial team for [Heliyon Genetics](#).



**Qiang Wu, PhD**

Dr. Qiang Wu is an associate professor in the State Key Laboratory of Quality Research in Chinese Medicine, Macau University of Science and Technology. He obtained his Ph.D degree from National University of Singapore in 2003. He then received his postdoc training in Genome Institute of Singapore (Mentor: Prof Huck Hui Ng) and the Gurdon Institute, University of Cambridge (mentor: Prof Magdalena Zernicka-Goetz). He went back to National University of Singapore as an assistant professor in 2009. He joined Macau University of Science and Technology in 2017.

Dr. Wu's research interest is to study how genetic and epigenetic factors determine stem cell fates and regulate cancer progression with a combination of molecular, cellular and high throughput approaches.

## Global Health & Infectious Diseases

Meet the full editorial team for [Heliyon Global Health & Infectious Diseases](#).



**Dr. Chaisiri Angkurawaranon**

Public Health

[Chiang Mai University](#), Chiang Mai, Thailand

Chaisiri Angkurawaranon received his MD from Chiang Mai University and specialises in Family Medicine. He received a Masters in Medical Statistics and a PhD in Non-communicable Disease Epidemiology from the London School of Hygiene and Tropical Medicine. His research focuses on global health issues related to ageing and chronic conditions (both communicable and non-communicable) in primary care.



**Assoc. Prof. Nitika Pant Pai**

Infectious Disease

[McGill University](#), Montreal, Canada

Dr. Nitika Pant Pai is a tenured Associate Professor in the Department of Medicine at McGill University. Her global implementation research program for the past twenty years is focused on point-of-care diagnostics for HIV and other sexually transmitted blood borne infections; specifically the innovation, implementation and impact of digital strategies with rapid diagnostics and wearable solution. She develops integrated connected strategies with digital innovations, Bayesian diagnostics, artificial intelligence to plug health service delivery gaps in diagnostics in rapid diagnostics. She serves to inform domestic and global policy on point-of-care diagnostics.

Her research program is based in Canada, India and South Africa. She has led many diagnostic trials, cohort/cross sectional studies, meta-analyses, systematic reviews, modelling studies, to inform the gaps in policies to end the HIV epidemic. Her research has been supported by grants from the Canadian Institutes of Health Research, the FRQS, Grand Challenges Canada, Bill and Melinda Gates Foundation, National Institutes of Health, MRC SHIP, South African DST, IC-IMPACTS, Clinton Health Access Initiative, among others.

She has served on many technical working groups for national and international agencies: WHO, Foundation for Innovative Diagnostics, PSI, The Bill and Melinda Gates Foundation, ASLM, CDC, PHAC, REACH, among others. She has advised the office of the US Congress on multiplex testing. She has also contributed to HIV self-testing guidelines and policy guidance for HIV self-testing for the WHO. She serves the Strategic Advisory Board of the Foundation for Innovative Diagnostics and is on WHO's Roster of Digital Health Experts. She serves on the Editorial Moard for biomedical journals and regularly reviews for key international health agencies.

She is an elected member of the College of New Scholars, Artists & Scientists of the Royal Society of Canada.





**Dr. Marcos Roberto Tovani-Palone**

Marcos Roberto Tovani Palone completed his MSc from the Hospital for Rehabilitation of Craniofacial Anomalies, University of São Paulo, Brazil, and PhD in Experimental Pathology from Ribeirão Preto Medical School, University of São Paulo, Brazil. He is a DDS specializing in different fields of health, including pediatric dentistry, syndromes and craniofacial anomalies, health management, and health surveillance. He has published more than 100 papers in reputed journals and has been serving as an editorial board member of important biomedical journals. His main research interests focus on pediatric pathology, orofacial clefts, general medicine, dentistry, global and public health. More recently in 2021, he obtained the degree of Public Administration. With an ongoing involvement in many projects and high impact research activities, he has established important international collaborations with researchers from all over the world.

## Immunology

Meet the full editorial team for [Heliyon Immunology](#).

**Mats Waldemar Johansson, PhD**

Immunology, Eosinophils

Dr. Mats W. Johansson received his PhD degree in biology within the research field of invertebrate immunology/innate immunity at Uppsala University, Sweden, was a postdoctoral fellow in cell biology at the Sanford Burnham Prebys Medical Discovery Institute, La Jolla, California, USA, and was then an Assistant and Associate Professor, and Director of Studies of biology at Uppsala University. He is currently a Senior Scientist and Research Professor (honorary) at the Morgridge Institute for Research, Madison, Wisconsin, USA, and affiliated as an Honorary Associate/Fellow with the Division of Allergy, Pulmonary and Critical Care Medicine of the Department of Medicine and the Department of Biomolecular Medicine, University of Wisconsin-Madison. Since coming to Madison he has done research on eosinophil biology, asthma, and eosinophilic esophagitis (EoE), and now recently also COVID-19.

## Information Science

Meet the full editorial team for [Heliyon Information Science](#).

**Prof. Gregorio González Alcaide**

Gregorio González-Alcaide (PhD) is a full Professor at the Department of the History of Science and Library & Information Sciences, at the University of Valencia.

Dr. González Alcaide teaching activities include Bibliometrics, skills in writing and academic communication and processes for evaluating research activities. He has also worked to raise awareness on the importance of academic honesty, to discourage behaviors like plagiarism and to foster respect for the ethical principles that must guide the research and publication process.

His main line of research has focused on the study of scientific collaboration by means of Bibliometrics and social network analysis as research methodologies. His studies have aimed to determine the extent of cooperative practices, structural properties, and the characteristics of scientific networks at different analytical levels (authors, institutions, and countries) and in different disciplines or areas of knowledge. He has also investigated cooperative practices as a process and researchers' perceptions with regard to this phenomenon, combining quantitative and qualitative approaches based on surveys and interviews.

## Materials science

Meet the full editorial team for [Heliyon Materials science](#).

**Prof. Luis M. Gandía**

Luis M. Gandía is a full professor of chemical engineering at the Public University of Navarre (UPNA) since 2010. Prof. Gandía obtained his Ph.D. in chemistry at the Faculty of Chemistry of the University of the Basque Country in Donostia/San Sebastián in 1993. He is a founding member of the Institute for Advanced Materials (InaMat) at UPNA. He is the head of a multi-disciplinary research team mainly working on renewable resources valorization and the development of catalytic materials for environmental and energy applications. His research interests include: preparation and physico-chemical characterization of heterogeneous catalysts; structured and micro-structured catalysts and chemical reactors; photocatalysis; biofuels and synthetic fuels; hydrogen energy; Li-ion batteries;

methane conversion; CO<sub>2</sub> valorization and Computational Fluid Dynamics (CFD).

## Mathematics

Meet the full editorial team for [Heliyon Mathematics](#).



**Prof. Hermann J. Eberl**

Dr. Hermann Eberl is a professor in the Department of Mathematics and Statistics at the University of Guelph (Canada), where he is also the director of the Biophysics Interdepartmental Graduate Program. Prior to joining the University of Guelph he obtained his graduate degrees (Dipl.Math., Dr.rer.nat) at the Technical University of Munich (Germany) and was a postdoctoral fellow first at the Delft University of Technology (the Netherlands), and then at the GSF National Research Center for Environment and Health in Oberschleissheim (Germany).

His research is in mathematical modelling, analysis, and simulation of biological systems and their interaction with their physical environment. This encompasses dynamical systems, partial differential equations, numerical analysis and scientific computing. The two primary strands of his research in recent years were the development and application of mathematical methods in biofilm research and mathematical modelling of honeybee colonies and their diseases.

## Microbiology

Meet the full editorial team for [Heliyon Microbiology](#).



**Assoc. Prof. Dana Stanley**

Associate Professor Dana Stanley was awarded a PhD in molecular microbiology from Victoria University, Melbourne, in 2009. Her PhD project, "Generation and Characterisation of Ethanol-Tolerant *Saccharomyces cerevisiae* Mutants," investigated the molecular and metabolic determinants of ethanol tolerance in yeast and was awarded "the most outstanding PhD in 2009" by the University. Prof. Stanley held a postdoctoral position in CSIRO's Animal Health Laboratories (AAHL), one of the world's most sophisticated animal research laboratories, where she researched poultry intestinal health, specifically gut microbiota and genetics. Currently, Prof. Stanley is a leader of the molecular microbiology research cluster at Central Queensland University, focusing in human and livestock intestinal health, probiotic and next generation antibiotic development and pathogen control. She is working in collaboration with world's leading probiotic companies on research projects aiming to improve intestinal health of agricultural animals and humans. Prof. Stanley's work has been published in *Nature Medicine* (as the first author), *Nature Communications* and *Nature Immunology*.

## Neuroscience

Meet the full editorial team for [Heliyon Neuroscience](#).



**Assoc. Prof. Mario Tiberi**

Dr. Mario Tiberi is a senior scientist at the Ottawa Hospital Research Institute's Neuroscience Program, and associate professor at the University of Ottawa Faculty of Medicine in the departments of medicine, cellular and molecular medicine, and psychiatry. He is also a member of the University of Ottawa Brain and Mind Research Institute. Dr. Tiberi completed his PhD in Pharmacology (1990) on opioid receptors at the Université de Montréal under the supervision of Dr. Jacques Magnan, before moving on to a very successful post-doctoral training at the Howard Hughes Medical Institutes at Duke University in Dr. Marc Caron's laboratory. It was during his postdoctoral training that Dr. Tiberi refined his area of research expertise in molecular biology and biochemistry of dopamine receptors. His research interests focus on dopamine receptors, G proteins, signal transduction, desensitization and phosphorylation. Dr. Tiberi's work aims to understand complex structure and molecular relationships of dopamine receptor signaling complexes using in vitro cellular systems and pre-clinical in vivo models, with the aim of aiding in the development of novel therapeutic strategies for brain disorders such as Parkinson's disease, stroke, schizophrenia and drug addiction. Dr. Tiberi has published over 50 scientific papers and edited two books. He has wide experience with undergrad and graduate student supervision as well as teaching. Many of his former graduate students have gone on to successful independent research careers.

## Pharmaceutical science, pharmacology and toxicology

Meet the full editorial team for *Heliyon Pharmaceutical science, pharmacology and toxicology*.



**Prof. Emilio Clementi**

Emilio Clementi graduated in medicine and surgery at the University of Milano, received his doctorate in pharmacotherapy at the University of Brescia to move as research fellow to the University College London. He is currently full professor of pharmacology and director of the clinical pharmacology unit of the National Health System at the University of Milano, co-opted member in the executive committee of the International Union of basic and clinical Pharmacology (IUPHAR).

He has published on the pathophysiology of nitric oxide and its relevance in therapeutic perspective, especially in skeletal muscle, and on pharmacokinetics, pharmacogenetics and pharmacoepidemiology in paediatrics. He is presently the editor in chief of pharmacological research.



**Prof. Dimitrios Lamprou**

Dimitrios Lamprou (Ph.D. MBA) is a reader in pharmaceutical engineering and the MSc programme director in industrial pharmaceuticals at the School of Pharmacy in Queen's University Belfast (UK). He is also the chair at United Kingdom and Ireland Controlled Release Society (UKICRS). Dr. Lamprou specialises in the areas of pharmaceutical manufacturing & emerging technologies and his research and academic leadership have been recognised in a range of awards, including the Royal Pharmaceutical Society Science Award and the Scottish Universities Life Sciences Alliance Leaders Scheme Award. His group is applying nano and microfabrication techniques in pharmaceutical and medical device manufacturing, such as 3D printing & bioprinting, electrospinning and microfluidics.



**Dr. Martin Leonard**

Dr. Leonard obtained his PhD in pharmacology in 2000 from University College Dublin, Ireland. He has over 15 years' experience as a toxicologist focussed to developing and improving on models and methods for assessment of toxicological hazard, including the use of high content omics technology and iPSC in vitro models of the airway. Dr. Leonard is a European registered toxicologist and currently holds a position as principal toxicologist at Public Health England directing research into the mechanisms of allergen and particulate hazard associated with asthma and allergic airway disease. Dr. Leonard has published extensively in the fields of toxicology, cell biology and immunology. In addition to section editor at Heliyon, he is also associate editor for the journal Toxicology in Vitro.

## Physics

Meet the full editorial team for *Heliyon Physics*.



**Prof. Gerald Cleaver**

Gerald B. Cleaver earned his Ph.D. in early universe cosmology and string theory at Caltech. He is a professor and graduate program director of the department of physics at Baylor University in Waco, Texas. He also heads the Early Universe Cosmology and String Theory (EUCOS) division of Baylor's Center for Astrophysics, Space Physics and Engineering Research (CASPER).

With CASPER colleagues, Prof. Cleaver (i) explores quantum gravity effects in the early universe and the signatures of specific quantum gravity proposals, especially with regard to the cosmic microwave background (CMB), (ii) studies relativistic thermodynamics and physics & cosmology applications to cryptography, (iii) analyzes spacetime curvatures (and their possible divergences) for theorized spacetime wormholes, and (iv) investigates advanced spacecraft propulsion systems. Prof. Cleaver was a member of a NASA blue-ribbon review committee for advanced propulsion system proposals. He has written over 100 journal articles and conference proceedings, is co-author of an elementary particle physics textbook, author of six book chapters, on the editorial board of four science journals, and referee for nine physics journals.

## Psychology



Meet the full editorial team for [Heliyon Psychology](#).



**Dr. Pavica Sheldon**

Prof. Pavica Sheldon received her PhD in communication studies from Louisiana State University, and currently serves as chair and associate professor in the Department of Communication Arts at University of Alabama in Huntsville. Dr. Sheldon is an author of three books and over 40 journal articles, studying uses and gratifications of social media, and also how people communicate forgiveness in interpersonal relationships.

## Quantitative biology, biotechnology and bioengineering

Meet the full editorial team for [Heliyon quantitative biology, biotechnology and bioengineering](#).



**Dr. Andrea de Martino**

Andrea De Martino received his PhD in theoretical physics from SISSA (Trieste, Italy). He worked at the Hahn-Meitner-Institut (Berlin, Germany), the Italian Institute for the Physics of Matter (Rome, Italy) and Sapienza University (Rome) before joining the National Research Council and, more recently, the Italian Institute for Genomic Medicine in Turin, where he is part of the Statistical Inference & Computational Biology Unit.

Dr. De Martino is generally interested in the physics of living systems across multiple scales, from single cells to ecosystems. He works in broadly defined systems biology (computational & mathematical biology, genome-scale models, bioinformatics, etc.). Dr. De Martino's favorite questions revolve around the functional roles of cell-to-cell heterogeneities, the interplay between physiology and gene expression in proliferating vs quiescent cells, the processing of information by biological networks, and the emergence of multi-cellular and population-level behavior.

## Social science

Meet the full editorial team for [Heliyon Social science](#).



**Prof. P. Vigneswara Ilavarasan**

P. Vigneswara Ilavarasan (PhD - IIT Kanpur) is a professor of information systems at the Dept. of Management Studies, Indian Institute of Technology Delhi. He researches and teaches about the interaction of information and communication technologies (ICTs), society, and business.

Dr. Ilavarasan has been a visiting research fellow at United Nations University - School of Computing and Society (Macau) and School of Management, Curtin University (Perth). He is a recipient of the Outstanding Young Faculty Fellowship Award at IIT Delhi and Prof. M.N. Srinivas Memorial Prize of the Indian Sociological Society. He is also a senior research fellow at LIRNEasia, a leading regional ICT policy and regulation think tank. He has received large research grants from Dept of Science & Technology (Govt of India), ICSSR (India), IDRC (Canada), Oxford Analytica (UK), IPTS (European Commission), CIPPEC (Argentina) and IdeaCorp (Philippines). His research has appeared in various leading international journals and at numerous global conferences.





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