JPPIPA 10(6) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Utilization of Organic Waste as A Natural Detector of Formaldehyde on-Campus Snacks

Lilis Lismaya[1,2], Putut Marwoto[2*], Sunyoto Eko Nugroho[2]

[1] Department of Biology Education, Faculty of Teacher Training Education, Universitas Kuningan, Indonesia.
[2] Department of Science Education, Faculty of Mathematics and Natural Science, Universitas Negeri Semarang, Indonesia.

Received: June 12, 2023
Revised: March 22, 2024
Accepted: June 25, 2024
Published: June 30, 2024

Corresponding Author:
Putut Marwoto
pmarwoto@mail.unnes.ac.id

DOI: 10.29303/jppipa.v10i6.4255

Abstract: The aim of this research is to reduce household organic waste through the use of organic waste as a natural detector of formaldehyde content in food snacks. The organic waste used in this study was red garlic skins, dragon fruit skins and purple sweet potato skins. This research is an experimental research. The stages of the research started with the extraction of anthocyanins from the three organic wastes, direct detection of formalin and detection of food ingredients. The formalin concentrations tested were 0.5%, 1%, 2%, 5% and 25%. Detection ability can be seen from the color change between control and formalin treatment. Garlic skin produces a red extract, dragon fruit skin produces an orange extract, and purple sweet potato skin produces a deep red extract. Test results on 20 samples of food snacks around the campus using the three organic waste extracts proved that all samples contained formaldehyde in varying concentrations. The highest 50% formalin content was found in yellow noodles and meatballs. The conclusion is that purple beetle skin, dragonfruit skin, and red garlic skin can be used as natural detectors for formalin in campus snacks.

Keywords: Anthocyanins; Campus snack; Formalin; Organic waste

Introduction

In this modern era, concerns regarding the quality and safety of food have been on the rise. One significant issue of major concern is the use of formalin as a food preservative, including in popular campus snacks among students (Kewitz & Welsch, 1966). Formalin, or formaldehyde, is a chemical compound widely used in the food industry to extend the shelf life of products and prevent the growth of harmful microorganisms (Robichaud et al., 2021). However, excessive use of formalin can have negative impacts on human health.

Formalin is known to possess toxic effects that can cause serious health problems such as respiratory tract irritation, digestive system disorders, and potential long-term effects that could lead to cancer (Miah et al., 2013). Hence, it is crucial to introduce effective and safe methods for detecting formalin in food (Elshaer & Mahmoud, 2017), especially in campus snacks that are consumed daily by many students.

In recent years, research on the Aditya et al. (2021) has garnered attention from numerous researchers. Organic waste is often regarded as waste that needs to be discarded, while in reality, it contains compounds with reactive potential towards formalin. Several types of organic waste, such as leaves, fruit peels, and discarded vegetables, contain compounds that can react with formalin and produce observable color changes or chemical reactions (Maddaloni et al., 2020).

However, the implementation of utilizing organic waste as a formalin detector in campus snacks still faces several challenges (Ismail et al., 2021). There is a gap between the ideal and reality in the utilization of organic waste as a natural formalin detector in campus snacks. Ideally, all snacks sold on the market should be free from formalin usage (Zhang et al., 2021), and the methods used for formalin detection should avoid the use of hazardous chemicals and be environmentally friendly. Moreover, the utilization of organic waste as a formalin detector in snacks could reduce production costs and

How to Cite:
Lismaya, L., Marwoto, P., & Nugroho, S. E. (2024). Utilization of Organic Waste as A Natural Detector of Formaldehyde on-Campus Snacks. *Jurnal Penelitian Pendidikan IPA*, *10*(6), 3519–3526. https://doi.org/10.29303/jppipa.v10i6.4255

serve as a cheaper alternative compared to conventional formalin detection methods (Liu et al., 2021).

However, in reality, many cases of formalin usage in campus snacks are still being uncovered, and commonly used formalin detection methods employ hazardous chemicals such as picric acid and sodium hydroxide (Haley et al., 2021). Additionally, the effectiveness and efficiency of utilizing organic waste as a formalin detector in campus snacks still need to be investigated.

A study was conducted to examine the food safety of meat and fish products in Bandar Lampung. It was found that formalin is still widely used as a preservative in various processed meat and fish products (Salawati, 2019). Furthermore, formalin analysis was conducted on meatball and fresh noodles in the districts of Sukarame, Wayhalim, and Sukabumi. The research results showed that out of 30 meatball samples, 10 contained formalin, while 2 out of the fresh noodle samples contained formalin. This indicates that approximately 33.3% of the analyzed meatball samples and 6.66% of the analyzed fresh noodle samples circulating in three districts of Bandar Lampung were found to contain formalin, making them unsafe for long-term consumption (Schiefer et al., 2016). However, all of these studies still employed chemical substances as formalin detectors in food, necessitating the search for more environmentally friendly and effective solutions for formalin detection (Hossain et al., 2019). Therefore, research on the utilization of organic waste as a natural formalin detector in campus snacks needs to be conducted to find more environmentally friendly and effective solutions for formalin detection in food.

The utilization of organic waste as a natural detector for formalin in campus snacks is an intriguing concept with significant potential to enhance food safety within the campus environment (Mirzal et al., 2016). Organic waste, often regarded as waste material, actually contains compounds that can react with formalin and produce visible color changes or observable chemical reactions (Gumede et al., 2022).

Several types of organic waste can be employed as formalin detectors, including leaves, fruit peels, and discarded vegetables (Chong et al., 2022). The compounds present in organic waste can interact with formalin and generate noticeable color changes or observable chemical reactions (Ismail et al., 2021). The utilization of organic waste as a natural formalin detector offers several advantages. Firstly, organic waste is easily obtainable and abundant in our surroundings. By harnessing organic waste as a detector, we can reduce the amount of organic waste being discarded, mitigating potential environmental damage (Bush et al., 1995).

Secondly, formalin detection methods using organic waste tend to be more environmentally friendly compared to conventional methods that employ hazardous chemicals (Panzacchi et al., 2019). In the context of campus snacks, this method can help reduce the use of potentially harmful chemicals that may jeopardize human health (Yin et al., 2016). Thirdly, utilizing organic waste as a formalin detector in campus snacks can serve as a cost-effective and affordable alternative to conventional detection methods (Chen et al., 2020) . This can enhance the accessibility of formalin detection methods, allowing more parties to conduct testing and ensure the safety of consumed snacks.

In conclusion, the utilization of organic waste as a natural formalin detector presents a fascinating concept with numerous advantages. It not only aids in reducing organic waste and its potential environmental impact but also offers a more environmentally friendly, cost-effective, and accessible approach to formalin detection in campus snacks. In this context, this research aims to explore the utilization of organic waste as a natural formalin detector in campus snacks. By utilizing abundant organic waste as a detecting agent, we can reduce organic waste generation while simultaneously developing formalin detection methods that are more environmentally friendly and sustainable.

Through this research, the development of a simple, rapid, and cost-effective formalin detection method using organic waste as a natural detector is anticipated (Elshaer & Mahmoud, 2017). This method can be employed as an effective tool for real-time formalin detection in campus snacks, thereby assisting in protecting consumers from potential health hazards that may arise.

Additionally, this research can contribute to educating the public regarding the dangers of formalin and the importance of choosing safe and healthy food. Thus, this research is expected to make a significant contribution to enhancing awareness and food safety within the campus environment. In this article, the researchers will elucidate the methodology employed to test organic waste as a formalin detector in campus snacks, as well as discuss the results and potential implications of this research. The researchers firmly believe that this research will provide fresh insights and contribute to the development of innovative and sustainable formalin detection technology for food safety.

Method

This research method uses experimental research methods with research making extracts from shallot skin, purple sweet potato skin and dragon fruit skin to take anthocyanins and then test them directly on food samples suspected of containing formalin. This research was conducted on March 7-10, 2023, the place of research implementation in the Biology laboratory room of the Faculty of Teacher Training and Education, Kuningan University.

The population in this study is all campus snacks sold around the campus environment that may contain formaldehyde. The samples in this study are 20 types of campus snacks randomly selected from the population, which are suspected of containing formalin, all of these samples will be used in testing the utilization of organic waste as a natural detector of formalin.

The tools used in this research are scales, oven/microwave, test tubes, test tube racks, beakers, drop pipettes, stirring rods, stamper mortars, Petri dishes, knives, blenders, spoons, and sieves. The materials used in this study were shallot skin, purple sweet potato skin, dragon fruit skin, distilled water, ethanol, formalin, potassium permanganate ($KMnO_4$), aluminum foil, meatballs, yellow wet noodles, siomay, cilok, cilor, cimol, nuggets, and sukoi.

The procedure in the study begins with the preparation of anthocyanin extracts from three types of organic waste, namely shallot skin, purple sweet potato skin and dragon fruit skin. First, prepare and wash shallots, purple sweet potatoes and dragon fruit cleanly, wait until dry. Then the skin is peeled and weighed to determine the weight. Then the shallot skin, purple sweet potato and dragon fruit are wrapped using aluminum foil, put in the oven, set the temperature at 140o C with time for dragon fruit skin for 7 hours, purple sweet potato 4 hours, and dragon fruit skin for 30 minutes. Next, the shallot skin, purple sweet potato and dragon fruit that have been dried are mashed using a blender. Filter using a filter cloth to get a fine extract of shallot skin, purple sweet potato and dragon fruit.

Generally speaking, the research procedures carried out in this study it can be seen in Figure 1.

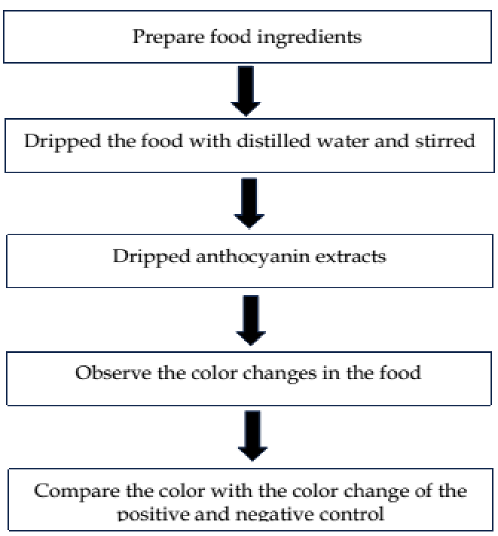

Figure 1. Research procedure

The fine extracts of shallot skin, purple sweet potato and dragon fruit were weighed and dissolved using ethanol with each ratio of 1: 11 for shallot skin and purple sweet potato skin, and 1: 5 for dragon fruit skin. Then the extract was filtered and put into a dark bottle for maceration process for 24 hours. Store the bottle in a place that is not exposed to direct sunlight/dark bottle then wait for 24 hours. After macerating for 24 hours, the extracts of shallot skin, purple sweet potato and dragon fruit can already be used to identify food ingredients that contain harmful substances such as formalin.

Next is the preparation of negative control solution with the following steps; first prepare pure extracts from each ingredient of shallot skin, purple sweet potato and dragon fruit, then add pure anthocyanin extract in a ratio of 1 : 2 between extract and distilled water. Observe the color produced by each pure extract in the recitation tube. Next is the manufacture of positive control solution in the following way: prepare pure extracts from each ingredient of shallot skin, purple sweet potato and dragon fruit, then put 1 ml of pure anthocyanin extract of each ingredient in a test tube, then add 9 ml of formalin solution to a test tube that already has 1 ml of pure extract, then homogenize the pure extract and formalin solution into a test tube with each concentration of 1%, 2%, 5%, 10%, and 25%.

Next, observe the color changes in the food ingredients that have been dripped with the extract. The next step is to identify food using anthocyanin extracts from shallot skin, purple sweet potato and dragon fruit skin, with the following steps: prepare food ingredients that have been mashed and will be tested, then the food is dripped with distilled water and stirred. Next, the anthocyanin extract solution from each ingredient (shallot skin, sweet potato and dragon fruit) is dripped, then observe the color changes in the food that has been dripped with the extract, and compare the color with the color change of the positive control solution and negative control. For comparison, also test the formalin content using $KMnO_4$.

Results and Discussion

The utilization of organic waste as a natural detector of formalin in campus snacks is proven to be possible through the use of shallot skin, purple sweet potato skin, and dragon fruit skin. The three types of skin waste were then dried, filtered and made into a positive control solution in the form of pure extracts from each ingredient of shallot skin, purple sweet potato and dragon fruit. The results of the pure extract can be seen in Figure 3. The results of the formalin test using purple sweet potato skin extract can be seen in Table 1.

Table 1. Formalin Test Results Using Purple Sweet Potato Skin Extracts

Negative control (-)		-
Positive control (+)	1%	IB meatballs, BR meatballs, nuggets, cilor
	2%	TL meatballs
	5%	Basreng, cilok, bakso BR chicken noodle, cilor
	10%	Meatballs AM, dumplings, otak-otak, dumplings KP, meatballs PI
	25%	Yellow noodle meatball PI, yellow noodle meatball TL, yellow noodle meatball IB, sukoi, meatball ML, yellow noodle meatball AM, yellow noodle meatball BR

Table 1 shows that all foods contained formaldehyde, but with different levels (percentage). The highest formalin content of 25% based on the test results using purple sweet potato extract was found in 4 types of yellow noodles and 3 types of meatballs sampled, and the rest in other snacks made from tapioca flour. These results can be seen after the sample food ingredients are dripped with purple sweet potato skin extract showing a color change reaction that matches the positive control. Purple sweet potato skin contains natural chemical compounds called anthocyanins (Dewi et al., 2014), as does shallot skin. Anthocyanins give the sweet potato skin its purple color and also act as natural antioxidants that are beneficial to human health.

The results of the formalin test using purple sweet potato skin extract can be seen in figure 2.

Figure 2. Formalin test results using purple sweet potato skin extracts

There are several reasons that may motivate sellers to use formalin in the snacks they sell, even though the use of formalin in food is unsafe and prohibited by food regulations (Schiefer et al., 2016). Some of these reasons include: Extending shelf life; formalin is an effective preservative that can prolong the shelf life of food products. By using formalin, sellers can reduce the risk of their products deteriorating or quickly becoming damaged (Biplob Hossain et al., 2019), allowing them to sell the products for a longer period of time. Maintaining appearance and texture; formalin can help preserve the appearance and texture of snacks, particularly in products like fish, meat, or perishable fruits (Akter & Bari, 2018). By using formalin, sellers can prevent color changes, physical damage, or excessive moisture in their products, thus keeping them visually appealing to consumers.

Reducing financial losses; in some cases, sellers may view the use of formalin as a way to mitigate the risk of financial losses resulting from spoiled or unsold products. By extending the shelf life of products using formalin, they hope to sell the products at full price before any damage or expiration occurs.

Increasing profits; the use of formalin can assist sellers in producing more products at a lower cost. By extending the shelf life of products, they can maintain larger inventories, reduce waste, and enhance profit potential.

It is important to note that the use of formalin in food is unsafe and prohibited by food regulations. Selling food products containing formalin poses significant risks to consumers and violates food safety regulations. Therefore, it is crucial for government authorities to take strong measures in monitoring and controlling such illegal practices to protect the public from the health hazards associated with the use of formalin in food. The results of formalin testing using red onion peel extract can be seen in Table 2.

Table 2 Formalin Test Results Using Onion Skin Extract

Negative control (-)		-
Positive control (+)	1%	
	2%	Cilok
	5%	Cilor, cimol, IB meatballs
	10%	Siomay KP, yellow noodle meatball PI, meatball TL, meatball PI
	25%	Basreng, otak-otak, nugget, sukoi, meatball ML, meatball IB yellow noodle, meatball TL yellow noodle, meatball BR yellow noodle, meatball AM yellow noodle, meatball AM, b meatball BR.

Table 2 shows that the highest formalin content was found in 6 types of meatballs sampled, as well as several types of campus snacks made from tapioca flour. This shows that there are still many sellers who are not aware of the dangers of using formalin in food. The 20 samples tested in this study can be seen in Figure 3.

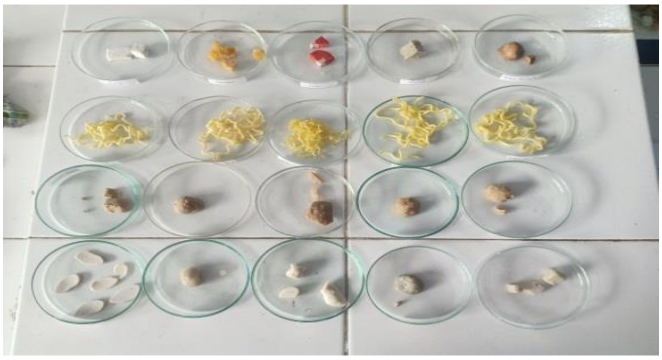

Figure 3. Food sample

Onion skin contains a natural chemical compound called anthocyanin. When anthocyanin reacts with formaldehyde, the color of the shallot skin will turn purple or purplish blue. This reaction is a natural detector of formaldehyde in food, including yellow wet noodles which are often targeted for formaldehyde addition by some irresponsible traders (Enjelina & Erda, 2022; Haley et al., 2021; Paine et al., 2018; Schiefer et al., 2016; Solanki et al., 2019).

The results of the formalin test using garlic skin extract can be seen in figure 4.

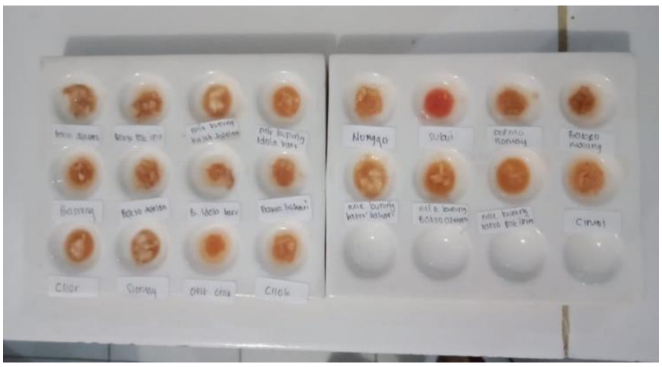

Figure 4. Formalin test results using garlic skin extracts

Besides using garlic skin extract, formalin content test was also conducted using dragon fruit skin extract. The results of the formalin test using dragon fruit skin extract can be seen in Table 3.

Table 3 shows that the highest formalin content was found in five yellow noodle samples and one meatball sample. This shows that there are still many sellers who are not aware of the dangers of using formalin in food. Formalin is widely used as an alternative in preserving food because it is cheap compared to permitted food preservatives such as sodium benzoate (Fauziyya & Saputro, 2020). This can be one of the reasons food sellers still use preservatives in the form of formalin, even though this is very detrimental to the health of consumers. The results of the formalin test using the three organic wastes can be seen in Table 4.

Table 3 Formalin Test Results Using Dragon Fruit Peel Extract

Negative control (-)		-
Positive control (+)	1%	Cilok
	2%	Cilor, BR meatballs
	5%	TL meatball yellow noodles, IB meatball yellow noodles,
	10%	Siomay KP, yellow noodle meatball AM, yellow noodle meatball PI, Cimol
	25%	AM meatballs, PI meatballs, BR meatballs, siomay, otak-otak, nuggets, ML meatballs, basreng, TL meatballs, IB meatballs, sukoi.

For comparison, researchers have also conducted a qualitative test of formalin content using Potassium Permanganate ($KMnO_4$). Potassium permanganate ($KMnO_4$) is used to detect formalin content in food because $KMnO_4$ has the ability as a strong oxidizer (Sandra et al., 2022). Oxidizers are chemical substances that can reduce other compounds by releasing electrons, and in this case, $KMnO_4$ can reduce formalin in food samples. The results of the formalin test using dragonfruit skin extract can be seen in figure 5.

Figure 5. Formalin test results using dragonfruit skin extracts

Formalin is a chemical compound that is often used as a preservative in food (Hossain et al., 2019; Mirzal et al., 2016; Pandey, 2000). However, formalin is also known as a substance that can harm human health, if consumed in excessive amounts (Saputri et al., 2019). Therefore, to ensure that the food consumed is safe and does not contain formalin, formalin test with $KMnO_4$ is often used as one of the methods of formalin detection in food (Kiroh et al., 2019).

In the formalin test with $KMnO_4$, formalin is reduced by $KMnO_4$, producing formic acid and oxygen compounds such as MnO_2 (Sari et al., 2017). This reaction causes a change in the color of the $KMnO_4$ solution from purple to yellowish brown. This color change indicates the presence of formalin in the food sample. The results of the formalin content test using $KMnO_4$ can be seen in Table 4.

Table 4. Formalin Test Results Using $KMnO_4$

Negative control (-)	-
Positive control (+)	Meatballs IB, bakso BR, nuggets, cilor, meatballs TL, basreng, cilok, meatballs BR chicken noodles, cilor, meatballs AM, siomay, otak-otak, siomay KP, meatballs PI, meatballs PI yellow noodles, meatballs TL yellow noodles, meatballs IB yellow noodles, sukoi, meatballs ML, meatballs AM yellow noodles, meatballs BR yellow noodles.

From table 4, the results of the formalin content test using $KMnO_4$ tested on food directly show that all foods used as test samples are positive for formalin, as evidenced by the final color results obtained in testing food samples, the results of color changes become clear after being tested with $KMnO_4$ so it can be concluded that the sample is positive for formalin (Adwiria et al., 2019). This shows the lack of awareness of food vendors around campus of the dangers of formalin. Formalin is known to cause dizziness, nausea, and skin irritation (Freeman et al., 2009).

Previous research on funeral workers who embalmed using formalin showed that there was an increased risk of blood cancer in these workers (Hauptmann et al., 2009). The utilization of organic waste as a natural detection material for formalin in campus snacks has not been widely done, even though this has several advantages. First, the detection material used comes from natural organic materials that are easily available and not harmful to human health. Second, the use of organic materials can help reduce the amount of waste disposed to the environment, thus reducing the negative impact on the environment (Medicine et al., 2022). Purple sweet potato skin, dragon fruit skin, and shallot skin contain chemical compounds that can react with formalin (Liu et al., 2021; Paine et al., 2018; Schiefer et al., 2016), so they can be used as natural detection materials for formalin in campus snacks.

Purple sweet potato skin contains phenolic compounds such as anthocyanins, flavonoids, and tannins that can react with formaldehyde and produce color changes (Alappat & Alappat, 2020; Enaru et al., 2021; Tan et al., 2022). Anthocyanin compounds in purple sweet potato skin are known to have the ability as pH indicators and can produce color changes based on the acidity of a solution.

Dragon fruit skin contains betasianin and betasianidin compounds that can also react with formalin and produce color changes (Aiadkaeo et al., 2022). These betasianin and betasianidin compounds are also known to have the ability as pH indicators and can produce color changes based on the acidity of a solution. Onion skin contains flavonoid and quercetin compounds that can react with formalin and produce color changes. The quercetin compound in shallot skin is also known to have the ability as an antioxidant and can help protect body cells from free radical damage (Octaviani et al., 2019).

Although the chemical compounds in these three organic wastes can react with formalin and produce color changes, further research needs to be done to ensure the accuracy and reliability of these natural detection materials in detecting the presence of formalin in food and beverage products.

This study still has some weaknesses. First, this study was only conducted on campus snacks and has not been tested on other food or beverage products. Secondly, this study was only conducted on a laboratory scale and has not been tested on a larger scale. Therefore, further research needs to be done to expand the application of this natural detection material on various food and beverage products and tested on a larger scale.

Conclusion

From the observation of color changes after being reacted with extracts of purple sweet potato skin, garlic skin and dragon fruit skin covering 20 samples of food snacks around campus consisting of 6 samples of meatballs, 5 samples of yellow noodles, 2 samples of siomay, 1 sample of chicken noodles, 1 sample of otak-otak, 1 sample of cilok, 1 sample of cilor, 1 sample of nuggets, 1 sample of basreng, and 1 sample of sukoi, all samples were shown to contain formalin with varying concentrations ranging from 1%, 2%, 5%, 10% and 25%, so it is not safe for long-term consumption and students and the wider community must be careful in choosing snacks around campus. Based on the results of this study, it can be concluded that purple sweet potato skin, dragon fruit skin, and garlic skin can be used as natural detection materials for formalin in campus snacks. The use of these natural detection materials has the potential to help ensure the safety of food and beverage products consumed by the community. In addition, the utilization of organic waste as a natural detection material can also help reduce the amount of waste disposed of into the environment.

Acknowledgements

This paper is part of the first author's doctoral study at Universitas Negeri Semarang. The author would like to thank Universitas Negeri Semarang.

Author Contributions

Literature review, L. L, P. M, S. E. N; Method, P. M, S. E. N; Laboratory tests, L. L, S. E. N; Analysis, L. L, P. M, S. E. N.

Funding

This research uses self-financing researchers.

Conflicts of interest

There is no conflicts of interest in this article.

References

Aditya, S., Stephen, J., & Radhakrishnan, M. (2021). Utilization of eggshell waste in calcium-fortified foods and other industrial applications: A review. *Trends in Food Science and Technology*, 115. https://doi.org/10.1016/j.tifs.2021.06.047

Aiadkaeo, N., Rianglaem, T., Lila, P., Pin-ngam, S., Saeyang, N., Jongrattanamongkon, S., Kunchanaroj, P., & Kasikitkonkun, K. (2022). A Case study: An Investigation of Borax in Meatball Products Sold in Bangkok, Thailand. *International Journal of Research Publications*, *110*(1). https://doi.org/10.47119/ijrp1001101102022394

Akter, B., & Bari, L. (2018). Determination Of Formaldehyde In Commercial Noodles Collected From Dhaka City, Bangladesh, By High Performance Liquid Chromatography. *Annals. Food Science and Technology*, 19, (2). Retrieved from https://afst.valahia.ro/wp-content/uploads/2022/09/III.3_Akter.pdf

Alappat, B., & Alappat, J. (2020). Anthocyanin pigments: Beyond aesthetics. *Molecules*, *25*(23). https://doi.org/10.3390/molecules25235500

Bush, V. J., Moyer, T. P., Batts, K. P., & Parisi, J. E. (1995). Essential and toxic element concentrations in fresh and formalin-fixed human autopsy tissues. *Clinical Chemistry*, *41*(2). https://doi.org/10.1093/clinchem/41.2.284

Chen, M., Wang, H., Chen, X., Wang, F., Qin, X., Zhang, C., & He, H. (2020). High-performance of Cu-TiO2 for photocatalytic oxidation of formaldehyde under visible light and the mechanism study. *Chemical Engineering Journal*, *390*, 124481. https://doi.org/10.1016/J.CEJ.2020.124481

Chong, C. C., Cheng, Y. W., Ng, K. H., Vo, D. V. N., Lam, M. K., & Lim, J. W. (2022). Bio-hydrogen production from steam reforming of liquid biomass wastes and biomass-derived oxygenates: A review. *Fuel*, *311*. https://doi.org/10.1016/j.fuel.2021.122623

Elshaer, N. S. M., & Mahmoud, M. A. E. (2017). Toxic effects of formalin-treated cadaver on medical students, staff members, and workers in the Alexandria Faculty of Medicine. *Alexandria Journal of Medicine*, *53*(4). https://doi.org/10.1016/j.ajme.2016.11.006

Enaru, B., Drețcanu, G., Pop, T. D., Stănilă, A., & Diaconeasa, Z. (2021). Anthocyanins: Factors affecting their stability and degradation. *Antioxidants*, *10*(12). https://doi.org/10.3390/antiox10121967

Gumede, J. I., Hlangothi, B. G., Woolard, C. D., & Hlangothi, S. P. (2022). Organic chemical devulcanization of rubber vulcanizates in supercritical carbon dioxide and associated less eco-unfriendly approaches: A review. *Waste Management and Research*, *40*(5). https://doi.org/10.1177/0734242X211008515

Haley, L., Parimi, V., Jiang, L., Pallavajjala, A., Hardy, M., Yonescu, R., Morsberger, L., Stinnett, V., Long, P., Zou, Y. S., & Gocke, C. D. (2021). Diagnostic Utility of Gene Fusion Panel to Detect Gene Fusions in Fresh and Formalin-Fixed, Paraffin-Embedded Cancer Specimens. *Journal of Molecular Diagnostics*, *23*(10). https://doi.org/10.1016/j.jmoldx.2021.07.015

Hossain, B., Hassan, M., Faisal Abdulrazak, L., Masud Rana, M., Islam, M., & Saifur Rahman, M. (2019). Graphene-MoS2-Au-TiO2-SiO2 Hybrid SPR Biosensor for Formalin Detection: Numerical Analysis and Development. *Advanced Materials Letters*, *10*(9). https://doi.org/10.5185/amlett.2019.0001

Hossain, M. B., Rana, M. M., Abdulrazak, L. F., Mitra, S., & Rahman, M. (2019). Graphene-MoS2 with TiO2[sbnd]SiO2 layers based surface plasmon resonance biosensor: Numerical development for formalin detection. *Biochemistry and Biophysics Reports*, *18*. https://doi.org/10.1016/j.bbrep.2019.100639

Ismail, T. F., Othman, G. O., Othman, N. H., & Hassan, B. A. (2021). Study the Effects of Formaldehyde and Xylene Vapor on Lung and Testicular Tissue with Sperm Morphology of Adult Albino Rats. *Polytechnic Journal*, *11*(1). https://doi.org/10.25156/ptj.v11n1y2021.pp46-51

Kewitz, H., & Welsch, F. (1966). Ein gelber Farbstoff aus Formaldehyd und Kynurenin bei hexaminbehandelten Ratten. *Naunyn-Schmiedebergs Archiv Für Pharmakologie Und Experimentelle Pathologie*, *254*(2). https://doi.org/10.1007/BF00535898

Liu, J., Lei, Z. Y., Pang, Y. H., Huang, Y. X., Xu, L. J., Zhu, J. Y., Zheng, J. X., Yang, X. H., Lin, B. L., Gao, Z. L., & Zhuo, C. (2021). Rapid diagnosis of disseminated Mycobacterium mucogenicum infection in formalin-fixed, paraffin-embedded specimen using next-generation sequencing: A case report.

World Journal of Clinical Cases, *9*(20). https://doi.org/10.12998/wjcc.v9.i20.5621

Maddaloni, M., Vassalini, I., & Alessandri, I. (2020). Green Routes for the Development of Chitin/Chitosan Sustainable Hydrogels. *Sustainable Chemistry*, *1*(3). https://doi.org/10.3390/suschem1030022

Miah, M. F., Tania, T. K., Begum, N. N., & Khan, Z. K. (2013). Effects of Formalin Contaminated Food on Reproductive Cycle and Lifespan of Drosophila Melanogaster. *Advances in Zoology and Botany*, *1*(3). https://doi.org/10.13189/azb.2013.010304

Mirzal, J., Rinidar, R., Razali, R., Sugito, S., & Nurliana, N. (2016). Deteksi Cemaran Boraks, Formalin, Analisis Proksimat serta Persepsi Pembeli dan Pedagang Bakso yang Berada di Kota Lhokseumawe. *Jurnal Teknologi Dan Industri Pertanian Indonesia*, *8*(2). https://doi.org/10.17969/jtipi.v8i2.6269

Paine, M. R. L., Ellis, S. R., Maloney, D., Heeren, R. M. A., & Verhaert, P. D. E. M. (2018). Digestion-Free Analysis of Peptides from 30-year-old Formalin-Fixed, Paraffin-Embedded Tissue by Mass Spectrometry Imaging. *Analytical Chemistry*, *90*(15). https://doi.org/10.1021/acs.analchem.8b01838

Pandey, C. K. (2000). Toxicity of ingested formalin and its management. *Human and Experimental Toxicology*, *19*(6). https://doi.org/10.1191/096032700678815954

Panzacchi, S., Gnudi, F., Mandrioli, D., Montella, R., Strollo, V., Merrick, B. A., Belpoggi, F., & Tibaldi, E. (2019). Effects of short and long-term alcohol-based fixation on Sprague-Dawley rat tissue morphology, protein and nucleic acid preservation. *Acta Histochemica*, *121*(6). https://doi.org/10.1016/j.acthis.2019.05.011

Robichaud, V., Bagheri, L., Salmieri, S., Aguilar-Uscanga, B. R., Millette, M., & Lacroix, M. (2021). Effect of γ-irradiation and food additives on the microbial inactivation of foodborne pathogens in infant formula. *LWT*, *139*. https://doi.org/10.1016/j.lwt.2020.110547

Salawati, A. A. W. (2019). Analisis kandungan formalin pada bakso yang diperjualbelikan di sekitar jalan abd.kadir kota makassar. *Jurnal Media Laboran*, *9*(1). Retrieved from https://jurnal.uit.ac.id/MedLAb/article/view/321

Saputri, F. A., Rosli, N. S. B., & Indriyati, W. (2019). Optimization of Sample Preparation Methods on Formaldehyde Analysis in Meatball with Schryver's Method. *Indonesian Journal of Pharmaceutical Science and Technology Journal Homepage*. Retrieved from http://jurnal.unpad.ac.id/ijpst/UNPAD

Schiefer, A. I., Parlow, L., Gabler, L., Mesteri, I., Koperek, O., Von Deimling, A., Streubel, B., Preusser, M., Lehmann, A., Kellner, U., Pauwels, P., Lambin, S., Dietel, M., Hummel, M., Klauschen, F., Birner, P., & Möbs, M. (2016). Multicenter Evaluation of a Novel Automated Rapid Detection System of BRAF Status in Formalin-Fixed, Paraffin-Embedded Tissues. *Journal of Molecular Diagnostics*, *18*(3). https://doi.org/10.1016/j.jmoldx.2015.12.005

Solanki, R., Solanki, M. K., Hemrajani, D., & Saha, J. (2019). A study of detection and comparison of immunofluorescence on formalin-fixed paraffin-embedded tissue with fresh frozen renal biopsy specimen. *Saudi Journal of Kidney Diseases and Transplantation : An Official Publication of the Saudi Center for Organ Transplantation, Saudi Arabia*, *30*(2). https://doi.org/10.4103/1319-2442.256842

Tan, J., Han, Y., Han, B., Qi, X., Cai, X., Ge, S., & Xue, H. (2022). Extraction and purification of anthocyanins: A review. *Journal of Agriculture and Food Research*, *8*. https://doi.org/10.1016/j.jafr.2022.100306

Yin, Z. Y., Li, L., Chu, S. S., Sun, Q., Ma, Z. L., & Gu, X. P. (2016). Antinociceptive effects of dehydrocorydaline in mouse models of inflammatory pain involve the opioid receptor and inflammatory cytokines. *Scientific Reports*, *6*. https://doi.org/10.1038/srep27129

Zhang, R., Qi, Y., Ma, C., Ge, J., Hu, Q., Yue, F. J., Li, S. L., & Volmer, D. A. (2021). Characterization of Lignin Compounds at the Molecular Level: Mass Spectrometry Analysis and Raw Data Processing. *Molecules*, *26*(1). https://doi.org/10.3390/MOLECULES26010178