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Preparation and Characterisation of Irradiated Beans Ink for Offset Lithography Printing

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ABSTRACT

Petroleum-based ink has been widely used around the world, especially in the offset of the lithography printing industry. However, it has negative consequences on the environment as well as the workers who are engaged with it. It includes volatile organic compounds (VOCs), which have a high vapor pressure at room temperature, such as toluene (C_7H_8). Peanut oil was used in this study to create an offset lithography ink. The objectives of this study are to investigate the physical and chemical properties of peanut beans, to study the effect on peanut oil during the pre- and post-irradiation, and to determine the appropriateness of ink to replace the use of petroleum-based ink. The preparation and characterization of this vegetable-based ink were then used to investigate its capability of becoming a good quality ink that does not bring harm to the consumer after being irradiated with gamma rays. About 15 ml of peanut oil was heated and mixed continuously with 1.5 g of 99% sodium hydroxide (NaOH) pellets for 30 min at a temperature of 133°C, to go through an alkali-refined process. The sieved solution was then added to 1 g of 99% butylated hydroxytoluene (BHT) powder, 1.5 g of 100% activated carbon, and 1 g of Arabic gum powder for 20 min, under the same temperature. After being irradiated, the intensities and viscosities of ink increased, compared to before it was irradiated by gamma rays. In the future, the concept of developing ink from vegetable oil has given rise to the concept of developing ink from peanut oil. This sort of ink was appropriate for usage in the offset lithography printing industry. The industry necessitated a greater use of ink for the manufacture of the majority of items we see today, such as newspapers, novels, comic books and magazines. It is far less expensive, and does not emit VOCs into the environment, which will have a negative consequence on a global scale.

1. Introduction

The invention of ink was one of the most significant progressions in human history during the early era of human civilization. Since prehistoric times, the ink has been formed using various substances [1]. Communities in the past recorded their life events through sculptures, carvings, pictographs, and verbal evidence. In 1457, the printing revolution started to take off. Today, the most

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popular ink is petroleum-based ink, having replaced vegetable-based ink in the 1960s. This ink is used in a variety of economic industrial developments, such as book and newspaper printing, food-packaging industries, and clothes printing [2].

However, the use of petroleum-based ink has negative effects on the earth, especially the environment. To counter these problems, a new type of vegetable-derived ink was introduced [3]. Various techniques are used to extract the oil from the vegetables, which are then processed as the main ingredient in the production process. The bean (Fabaceae) family is the best vegetable category used in the production of this ink is because the derived oil contains 60% polyunsaturated fat and 24% monounsaturated fat, making it heart-healthy oil [4]. Furthermore, it does not need the use of non-harmful solvents and does not produce operational issues in the process. For instance, only a small amount of solvent is required of cleaning the machinery after printing [5]. The most popular vegetable-based ink is made from soybeans; thus, to expand the usage of this type of ink, ink from peanuts that come from the same family of beans was produced [6].

Although petroleum-based ink has been used widely around the world, it brings a lot of adverse effects on humans and the environment. Traditional petroleum-based inks are environmentally hazardous. They contain volatile organic compounds (VOCs) that are very harmful to the environment, wildlife, and humans. They cause ozone pollution when released into the atmosphere after reacting with nitrogen oxides. The reaction causes health problems such as asthma, emphysema, and bronchitis, so printing workers are regularly exposed to health hazards unless they are protected. Other conventional inks carry harmful metallic substances such as cadmium (Cd), lead (Pb), and mercury (Hg) [7]. Besides, these inks are typically dull in color, which requires more ink to give a vibrant look when compared to vegetable-based inks, posing a cost-effective issue.

However, the use of soy-based ink has some disadvantages, including a longer drying time that increases the risk of ink rubbing. Various colors (such as white and reds) in the soy-based ink have shown the presence of metals zinc (Zn) and barium (Ba). These types of chemical elements are toxic substances that can affect the consumer. Furthermore, traditional inks based on natural pigments and soybean oil are temperature sensitive during the application process. This technique overcame the limitation that stocks printed with conventional ink based on natural pigment and soybean oil could not be heated. It is critical to creating a temperature-resistant, environmentally friendly ink based on natural pigments and soybean oil [8].

Numerous attempts have been made to address the environmental consequences of petroleum-based ink, which is also the primary reason for the presence of vegetable-based ink. Vegetable-based inks yield a limited range of colors that can be printed to produce vibrant, saturated colors. When the ink is printed on a coated paper with a combination of materials or polymers to achieve a few desired characteristics, such as weight and smoothness, it produces colors that are more intense visually. Therefore, if it is printed on uncoated paper, it will produce a lot of end products at a much-reduced cost compared to petroleum-based inks [9]. The pigment content is higher in offset printing because it is more viscous than other types of inks and the ink film is thinner. This type of ink can mitigate the color to get better mileage for printing [10].

Currently, the development of composite fruit and vegetable printing inks for printing applications shows that the ink based on peanut protein isolate has the best printing properties. The results showed that a composite fruit and vegetable ink based on peanut isolate protein has stable and better printing capabilities for a wide range of fruit and vegetable powders [11]. Meanwhile, the use of surface-active biopolymers opens up new possibilities for creating a well-defined printable ink for 3D printing. In this regard, an ideal ink must have pseudoplastic, viscoelastic, and thixotropic properties, as well as a recoverable structure, to be printed efficiently and with the appropriate printability. Various findings provide a thorough grasp of the printability and extrudability of these biomaterial groups [12]. Besides, the components of solvents, pigments, dyes, resins, lubricants, surfactants, particulate matter, fluorescents, and other materials were used to color a surface to create an image, text, or pattern. Different types of ink will sink or soak into the writing surface in certain ways, and different surfaces allow particular ink types to penetrate while rejecting others [13].

Printer capabilities, filament quality, and dimensional stability are all important aspects to consider for evaluating printing performance [14]. A technique for screening food inks for the capacity to build 3D structures with enough stiffness to be termed as dimensionally stable has been wonderfully discussed. Shape fidelity represents how closely the 3D-printed food structure follows the planned design in terms of form and dimension that is typically used to gauge print quality. Due to its superior characteristics of cheap cost, simple operability, and scalability, screen printing is recognized as a highly competitive manufacturing process for the scalable and quick production of printed microelectronics. However, screen printing functional ink limits its large-scale application in printed microelectronics [15].

This research determines the positive feedback from the use of vegetable-based ink, specifically ink made from peanut oil [16]. The virgin oil, extracted from the Fabaceae species peanuts, was heated and blended as one of the main ingredients to combine with other substances to produce ink. The resulting product was tested for its suitability before and after radiation treatments by gamma rays. Later, Fourier transforms infrared spectroscopy (FTIR) was used to identify the organic and inorganic materials in the sample and different intensities. Moreover, it was tested by a rheometer (plate/plate, cone/plate, and cylindrical measuring system) to measure the rheological properties and the viscosity of the product after it had been radiated. The results of the characterization process determined the suitability of peanut oil ink as an outstanding ink source.

2. Methodology

One-kilogram peanut beans from the Fabaceae species were selected as a material to be used in this study as shown in Figure 1. The well-dried peanut bean samples were purchased at the market.

(a) (b)

Fig. 1. One kilogram beans that were purchased at market (a) peanuts (b) soybeans

2.1 Heat Treatment Process

The peanuts and soybeans were heated twice. First, both samples were cooked for 15 min in a shallow pan on a gas stove at 50°C to soften the layer of bean skin and cook them within. Furthermore, oil and other components had to be combined by heating to generate vegetable-based ink from peanuts and soybeans [17].

2.2 Cleaning and Blending Process

After heating both samples, the outer layers of skin on the beans had to be peeled off. To get crushed small bean fragments, the beans had to be mixed (Figure 2). After blending, the tiny size of the beans contributed to shortening the time required to extract the oil.

(a) (b) (c)

Fig. 2. (a) Blending process (b) Crushed peanut bean after blending process (c) Crushed soybean after blending process

2.3 Extracting Process

The separation of oil refers to the extraction of a solid chemical from its base to get a liquid form, which is the oil. Three to five spoons of hot water were poured for each bean. After fully mixing the compound, a tiny volume was squeezed to release the oil. By placing the beaker beneath the oil filter, any unwanted substances combined with the oil were filtered out.

2.4 Alkali-refined Treatment and Sieving Process

As a result, 20 ml of each oil was mixed with 1.5 g of 99% sodium hydroxide (NaOH). The mixture had to be stirred using a heated plate (133°C for 30 min) and a magnetic stirrer to allow the NaOH to react with the oil. The solution becomes slightly viscous over time, and the colors will shift from yellowish to a slightly deeper yellow (Figure 3). The solutions must be sieved, and both procedures were performed on peanut and soybean oils.

Fig. 3. After undergoing alkali-refined treatment

2.5 Production of Ink

The extracted oil, which serves as a carrier, was then meticulously combined with the color and resin. The materials were mixed following Erhan *et al.,* [16,19], where the researchers used four distinct pigments to obtain the inks— black, yellow, blue, and ruby—from the extracted oils. However, in this experiment, only black color was used to create ink. The sieved refined oil contained a variety of other materials. Twenty ml of peanut oil was heated to the same temperature as the alkali-refined treatment, but the oil was mixed with 1 g of 99% butylated hydroxytoluene (BHT) powder, 1.5 g of 100% activated carbon as the ink pigmenting agent, and 1 g of Arabic gum powder as the resin to hold everything together.

(a) (b) (c) (d) (e)

Fig. 4. (a) and (b) Soybean ink from soybean oil (c) and (d) Peanut ink from peanut oil (e) The end product of vegetable-based ink

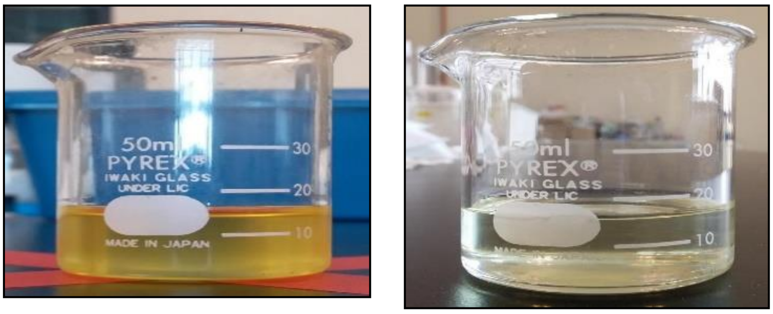
2.6 Sample Characterization

To determine the suitability of peanut oil for use in future ink, it had to be tested for pre- and post-irradiation (0.5 kGy, 1.0 kGy, 1.5 kGy, 2.0 kGy, and 2.5 kGy). Before being exposed to any radiation, the inks were evaluated using FTIR, rheometer (plate/plate, cone/plate, and cylindrical measuring system), and viscosity. The result showed the suitability of peanut oil for future ink manufacturing, especially in offset lithography printing industries [19].

3. Results and Discussion

Based on the processes proposed by Barros *et al.,* [6], the experiment showed that the physical properties of both beans can be differentiated by their sizes. Peanuts were twice the size and shape of soybeans. Soybeans had a brighter color than peanuts, which have a darker outer layer of skin but are more luminous on the inside. Soybeans, due to their hardness, required more heating time or a higher temperature to become tender and the skin to peel easily.

Due to its chemical properties, the oil smell from peanut beans was more comfortable and pleasant to inhale, whereas soybeans released a slightly pungent and strong smell. Soybean oil ranged in color from light yellow to almost transparent, whereas peanut bean oil was more aqueous and had a yellowish color. According to Ebong [22], peanut oil (a non-drying oil) has an Iodine (I) number that is less than 115, whereas drying soybean oil has an Iodine number greater than 116.



(a) (b)

Fig. 5. (a) Highly yellowish color and more aqueous peanut oil (b) Light yellow almost transparent soybeans oil

3.1 Fourier Transforms Infrared Spectroscopy (FTIR) Results
3.1.1 Pre radiation treatment

The samples were tested for the presence of any changes in their organic and inorganic materials before and after the irradiation process by gamma rays through the use of Fourier transform infrared spectroscopy (FT-IR). The FTIR results are as follows.

The table shows the groups present in the ink before any radiation treatment. Based on the graph shown in Figure 6, the characteristics of infrared absorption for some functional groups (found in soybean ink) showed more vigorous fluctuations compared to peanut ink. The presence of a halo compound in soybean ink showed a strong intensity, which occurred with a stretching vibration, but it was not found in the peanut ink. Alkene groups were only found in the soybean ink. Both inks had a strong intensity with a single carbon (C) and hydrogen (H) bond (C-H) with a bending vibration. This functional group was called a monosubstituted benzene derivative.

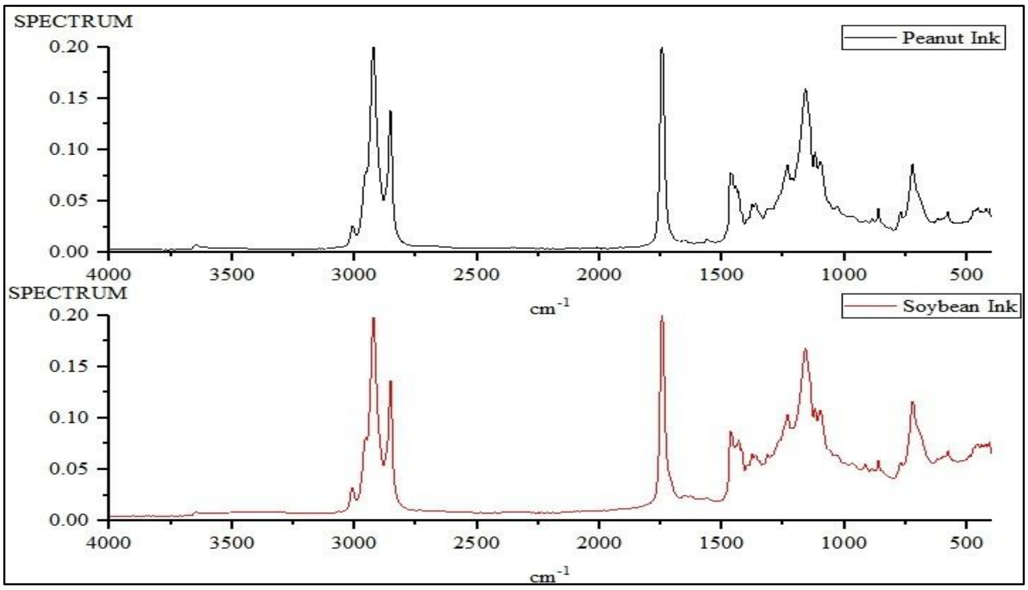


Fig. 6. The FTIR results of peanut and soybean ink before radiation treatment

The vinyl ether found in both inks was classified as having a strong intensity with a stretching vibration. Secondary alcohol with a single carbon-oxygen (C-O) bond had a high-intensity functional group, which was found in both inks, but only soybean ink had a tertiary alcohol group. Soybean ink contained alkyl, ether, aromatic ester, and aromatic amine but not peanut ink. The intensities of these three functional groups were stronger. Both inks had sulfone and sulfonamide functional groups ranging from 1370 cm-1 to 1120 cm-1. These groups were classified as having a strong intensity with a stretching vibration.

Both inks contained phenol and a carboxylic acid, but only the soybean ink had fluoro compound and alcohol. The ink had a medium intensity from phenol, but a stronger intensity from a carboxylic acid. The fluoro compound and alcohol were both strong-intensity functional groups with a stretching vibration. The absorbance bands for both inks changed starting at 1500 cm-1. According to the graph, soybean ink showed a higher intensity of both organic functional groups and carbonyl functional groups compared to peanut ink. Alkane groups ranged from 1350 cm-1 to 1480 cm-1 with a (-C-H) bond presented a bending vibration with variable intensity for the peanut and soybean inks. The graph revealed that the soybean ink had a stronger intensity before irradiation treatment, based on the values collected from the peak centers of each ink.

3.1.2 Post radiation treatment

For radiation treatment, 5 ink containers for each oil were prepared. Each ink sample was radiated with a different value of rays. For example, 5 ml of peanut ink and soybean ink were emitted by 0.5 kGy of gamma rays. These steps were followed for each sample with values of rays of 0.5 kGy, 1.0 kGy, 1.5 kGy, 2.0 kGy, and 2.5 kGy. The radiated samples were then tested again by the FTIR machine.

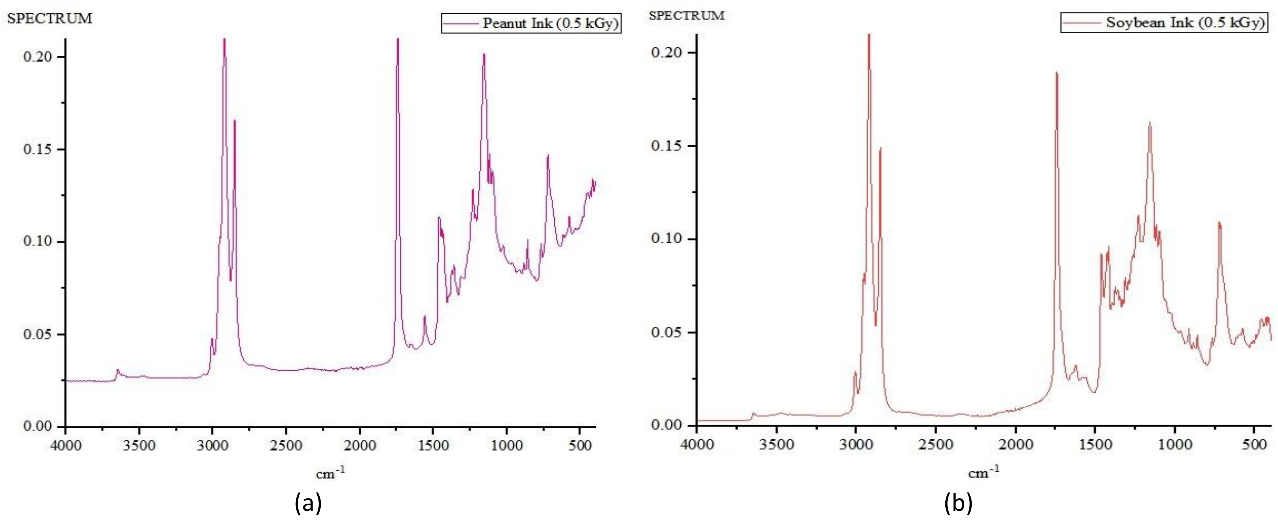
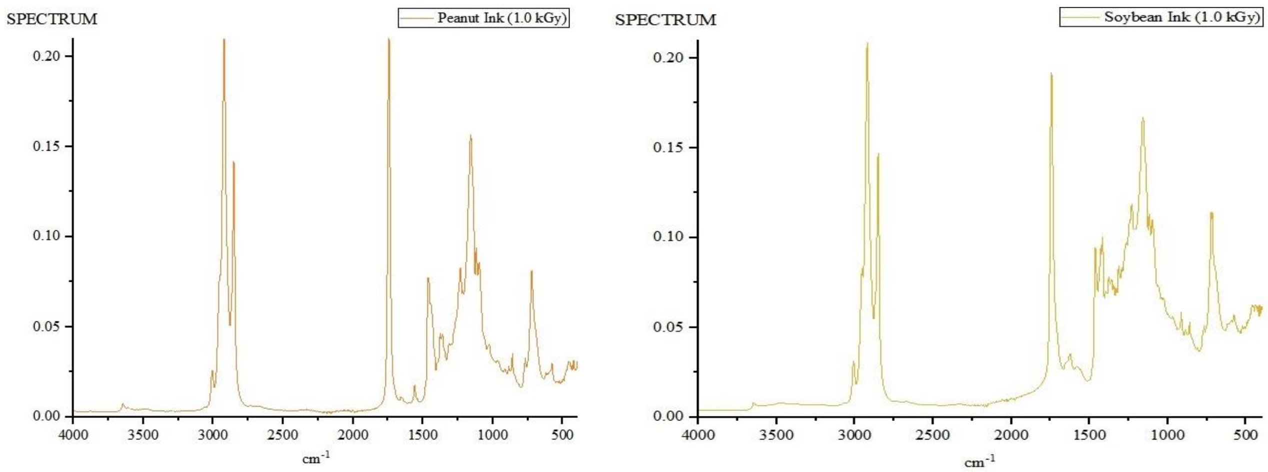


Fig. 7. The FTIR result of (a) peanut ink (b) soybean ink after radiated with 0.5 kGy of Gamma rays

After undergoing radiation treatment with 0.5 kGy, the intensity of peanut ink was stronger compared to soybean ink. From the peanut ink graph, the functional group was present with a stronger intensity ranging from 1550 cm-1 to 1640 cm-1. The oil contained many stronger bonds and stretching and bending vibration, but this group did not occur in the soybean ink graph. Instead, soybean ink had a medium intensity of functional group and through the detection of nitro compounds, which occurred from the single (N-O) bond.

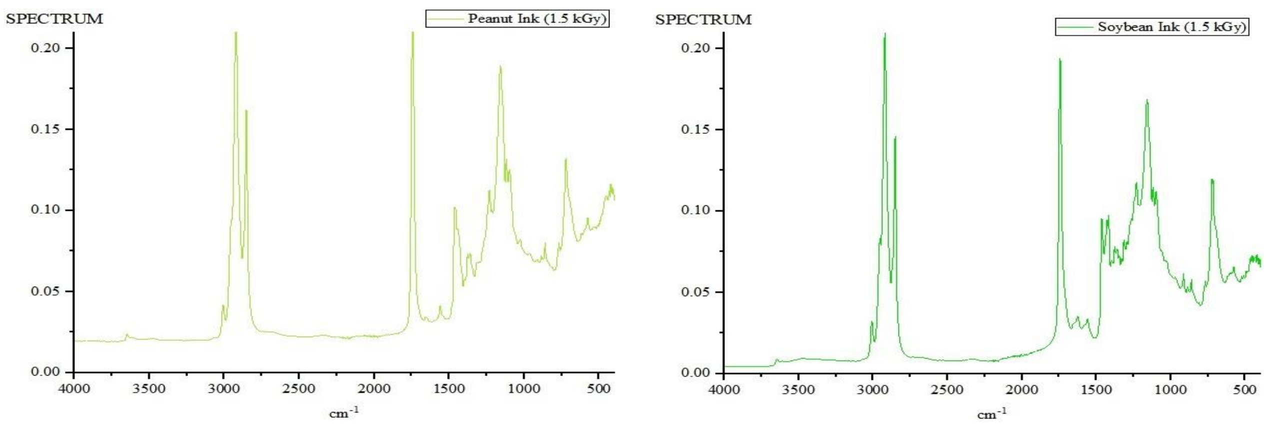


(a) (b)

Fig. 8. The FTIR result of (a) peanut ink (b) soybean ink after radiated with 1.0 kGy of Gamma rays

Under the radiation treatment of 1.0 kGy, the intensity of the peanut ink was stronger than that of the soybean ink. Many alkane groups are present in the peanut ink graph, and all of them showed medium intensity with various vibrations depending on their ranges. The (C-N) bond of aliphatic amines in peanut ink provided a stretching vibration towards it. However, the soybean ink graph had a variety of functional groups and a combination of strong and medium intensities. One of them was the aromatic groups with a medium intensity that happened from a (C-C) single bond.

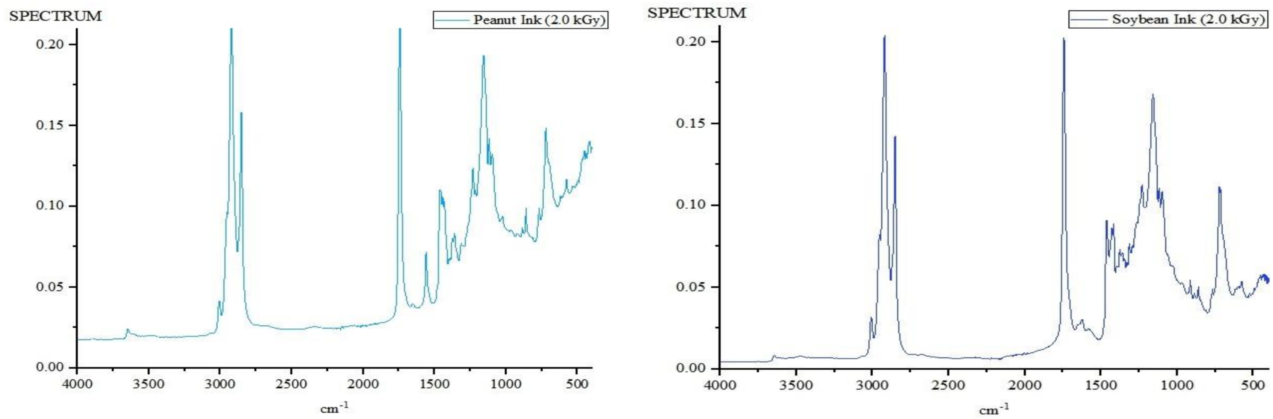
After undergoing radiation treatment with 1.5 kGy, the intensity of the soybean ink was weaker than that of the peanut ink. According to the graph of soybean ink in Figure 9(b), it had an organic nitro compound group (N-O) with symmetric stretch vibration of medium intensity, following its characteristic absorption from 1360 cm-1 to 1290 cm-1. The group was not found in the peanut ink graph.



(a) (b)

Fig. 9. The FTIR result of (a) peanut ink (b) soybean ink after radiated with 1.5 kGy of Gamma rays

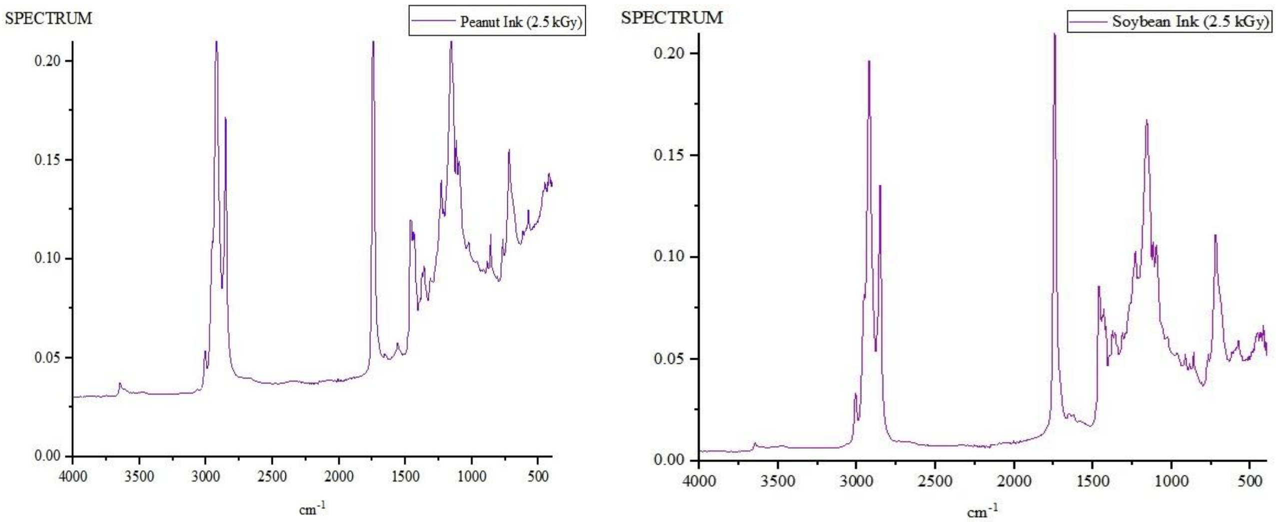
With a radiation treatment of 2.0 kGy in Figure 10(b), the intensity of soybean ink was stronger than that of the peanut ink. When comparing the peanut ink graph to the soybean ink graph, there were a lot of functional groups with medium intensities. The peanut ink had an aromatic group with a characteristic absorption of 1550 cm-1 to 1640 cm-1. It had a (C-C) bond and displayed stretching vibration. The soybean ink graph had an organic ester group (C=O) with a stretching vibration with a fickle intensity, ranging from 1750 cm-1 to 1735 cm-1.



(a) (b)

Fig. 10. The FTIR result of (a) peanut ink (b) soybean ink after radiated with 2.0 kGy of Gamma rays

After 2.5 kGy of radiation treatment (Figure 11), the intensity of soybean ink was more durable than that of the peanut ink. The organic alcohol (C-O) of a solid strength was detected in the soybean ink graph. The characteristic absorption ranged from 1050 cm-1 to 1150 cm-1, thus forming a stretch vibration. A similar observation was noted in the peanut ink graph.



(a) (b)

Fig. 11. The FTIR result of (a) peanut ink (b) soybean ink after radiated with 2.5 kGy of Gamma rays

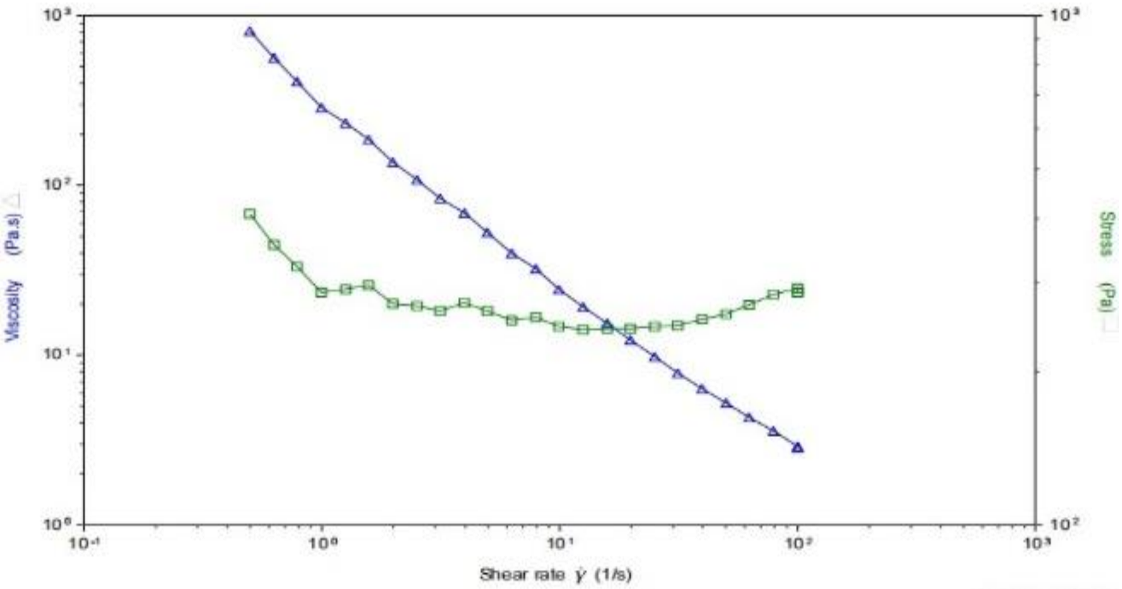
The correlation between the results of pre- and post-procedures for both inks can be seen through their intensities. Both inks had higher intensities after being radiated by gamma rays. From the graph, the peanut ink had a higher intensity than soybean ink after the radiation process. The ink's highest intensity contributed to a reduction in varnish from about 50% to 58%. When the varnish was lower, the density of the ink with other liquids was not affected. The oil dispersion varied from 8% to 15%, while the wax mixture ranged from 4% to 10%. Both conditions are important for increasing the effectiveness of the ink when it is used since it creates a greater bond between the mixture of substances. Apart from that, changes in the tints varied from 18% to 25%, producing a better color, and the drier mixture in the ink decreased from 1% to 3%. All of the percentages were measured based on the altered weight of the ink after testing.

The high ink intensity can provide a color space in the printing machine and produce color proof while printing. It is also recognized to produce very strong colors with fewer dots in each area than lower intensity inks.

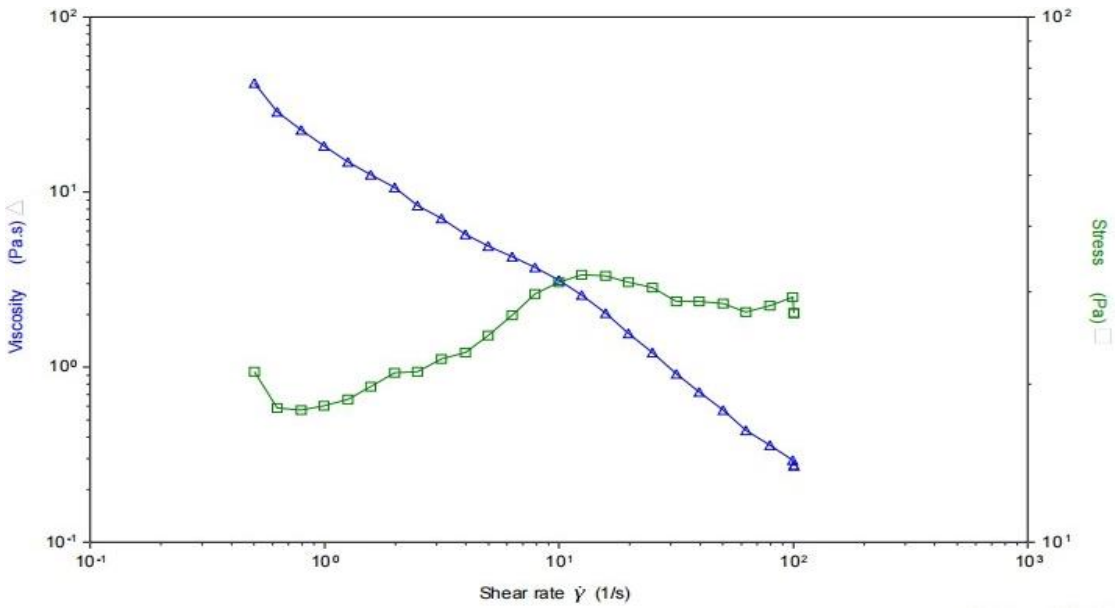
3.2 Rheometer Results
3.2.1 Pre radiation treatment

The rheology testing was used to measure the deformation of a sample under the change of imposed stress before gamma rays were emitted, and the results were plotted on different graphs for both inks. The peanut ink presented a declining plot of viscosity when the pressure given to the sample was changed from high to low and returned to high stress. The stress showed an upward curve line that determined the thermal effects on the sample viscosity (Figure 12). From points 4 to 6, the sample started to feel the growth of pressure from 285.9 Pa to 296.1 Pa, which decreased the viscosity from 286.6 Pa to 187.2 Pa. The pressure continuously decreased until it reached point 10, after which it rose to 272.6 Pa from 263.0 Pa at point 9. Following the decrease in viscosity, it gradually decreased after point 10. When the curve started to move up, there was the cross-linking phase that happened at point 16. The viscosity at that point was 15.3 Pa.s. The curve tended to flatten at the peak value of torque.

As for the soybean ink graph in Figure 12(b), the stress showed a downward curve line. The cross-linking phase occurred at point 14, where its viscosity was at 3.1 Pa.s, even when the stress given to the sample was rapidly changed from 21.0 Pa to 18.0 Pa. It lowered the viscosity of the sample from 42.1 Pa.s to 28.6 Pa.s in a shorter time. Starting from point 15, the curve line of stress decreased along with the line of viscosity until it reached point 25.



(a)



(b)

Fig. 12. Rheometer results of (a) peanut oil ink (b) soybean ink before radiation treatment

3.2.2 Post radiation treatment

Before beginning the radiation treatment, 5 containers of ink for each oil were prepared. Each ink sample was exposed to a different dose of gamma rays, with 0.5 kGy, 1.0 kGy, 1.5 kGy, 2.0 kGy, and 2.5 kGy. The samples were re-examined again by the Rheometer (plate/plate, cone/plate, and cylindrical measuring system) for any changes that may happen in their rheology properties and viscosities.

The stress curve from the peanut ink graph in Figure 13 shows a gradual decrease until point 17, and then it decreased directly from 132.8 Pa to 114.9 Pa after the samples were radiated with 0.5 kGy of gamma rays. The shear rate increased, indicating high friction between the surface of the rheometer plate and the ink. The viscosity from point 16 declined from 8.6 Pa.s. to 6.6 Pa.s. The cross-linking phase at point 12 presented a viscosity of 23.1 Pa.s. However, for soybean ink, the stress curve fluctuated vigorously (Figure 14) from point 7 to point 25. At point 8, the stress level increased slightly from 13.9 Pa to 14.6 Pa at point 7, before decreasing again. It increased from point 15 to point 16, indicating a direct change in viscosity due to the increased pressure and shear rate. However, a rapid decline from point 19 to point 20caused a clear difference in viscosity from 0.4 Pa.s. to 0.2 Pa.s. The shear rate between these two points was also higher due to the pressure provided. The graph cross-linking phase appeared at point 24 with a viscosity of 0.1 Pa.s.

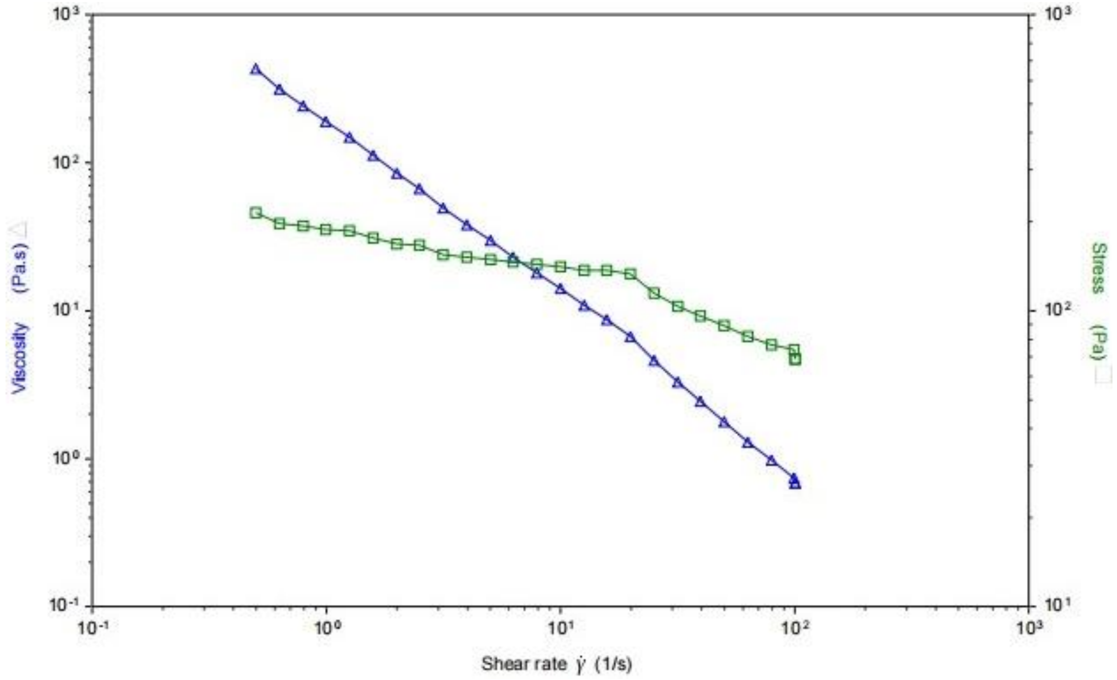


Fig. 13. Rheometer results of peanut ink after radiated with 0.5 kGy of Gamma rays

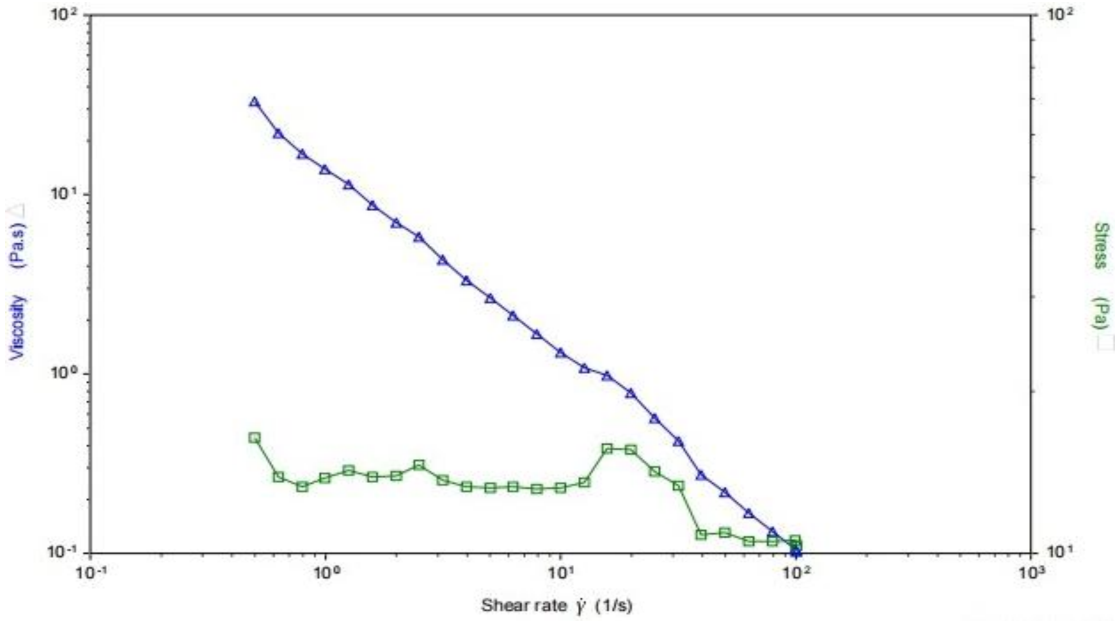


Fig. 14. Rheometer results of soybean ink after radiated with 0.5 kGy of Gamma rays

The graphs in Figure 15 and Figure 16 show the results after gamma rays of 1.0 kGy were emitted towards the samples. The stress curve from the peanut ink graph showed a slower decreasing pressure. A small downwards curve was observed in the graph from point 1 to point 6. At point 6, the pressure was high at 474.5 Pa with a viscosity of 300.1 Pa.s. It reached the cross-linking stage between points 10 and 11. Thus, the viscosity ranged between 118.5 Pa.s. and 95.4 Pa.s. However, in the soybean ink graph, a small upwards curve occurred from point 1 to point 6. However, instead of showing a decreasing plot, the stress curve started to grow at point 11 with a stress value of 23.7 Pa and a shear rate of 5.0 1/s, which resulted in the presence of the intersect link at point 15 before returning to point 17. The viscosity recorded was at 2.3 Pa.s. The curve line plotted by the stress value of the soybean ink presented the same pattern of growth as the graph of soybean ink before being radiated by 0.5 kGy before, where it fluctuated actively.

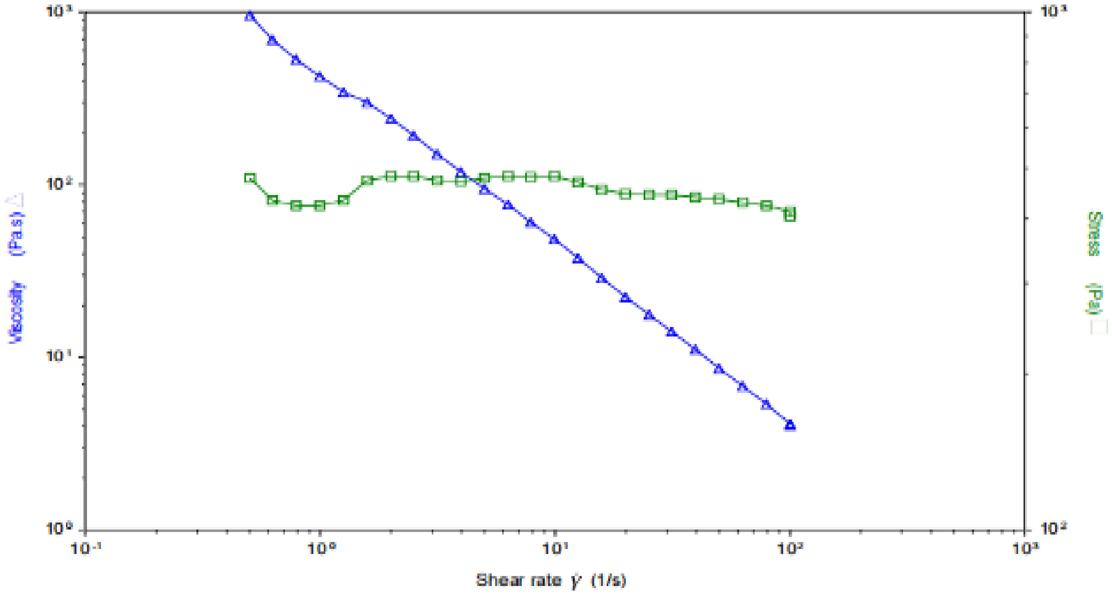


Fig. 15. Rheometer results of peanut ink after radiated with 1.0 kGy of Gamma rays

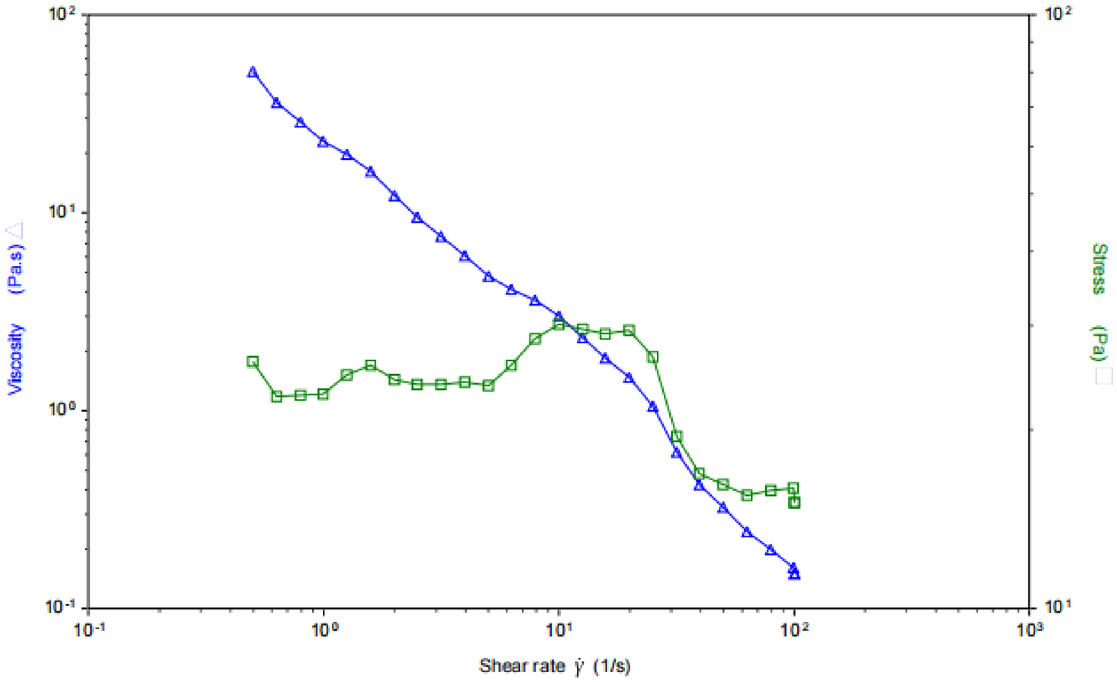


Fig. 16. Rheometer results of soybean ink after radiated with 1.0 kGy of Gamma rays

For 1.5 kGy in Figure 17, the peanut ink graph had a stress curve that intersected faster towards the decreasing viscosity. At point 2, the cross-linking phase showed a viscosity of 845.7 Pa.s. After the intersection, both plotted lines declined, but the stress curve indicated a slight increase at point 8 when 525.7 Pa was exerted on the sample. It reduced the viscosity from the previous point, from 249.0 Pa.s. to 209.7 Pa.s. The decrease was slightly faster between points 17 and 18 than at the other points. It changed the viscosity from 24.9 Pa.s. to 18.6 Pa.s. The shear rate at point 17 was less compared to point 18 as the sample showed a bit more reading reaction towards the pressure given before going down again slowly. The stress curve in Figure 18 from the soybean ink graph decreased together with the viscosity. But at point 14, it increased and caused the cross-linking phase to occur at point 15 with a viscosity of 6.7 Pa.s. It constantly grew until it reached point 18, after which the graph began to decline.

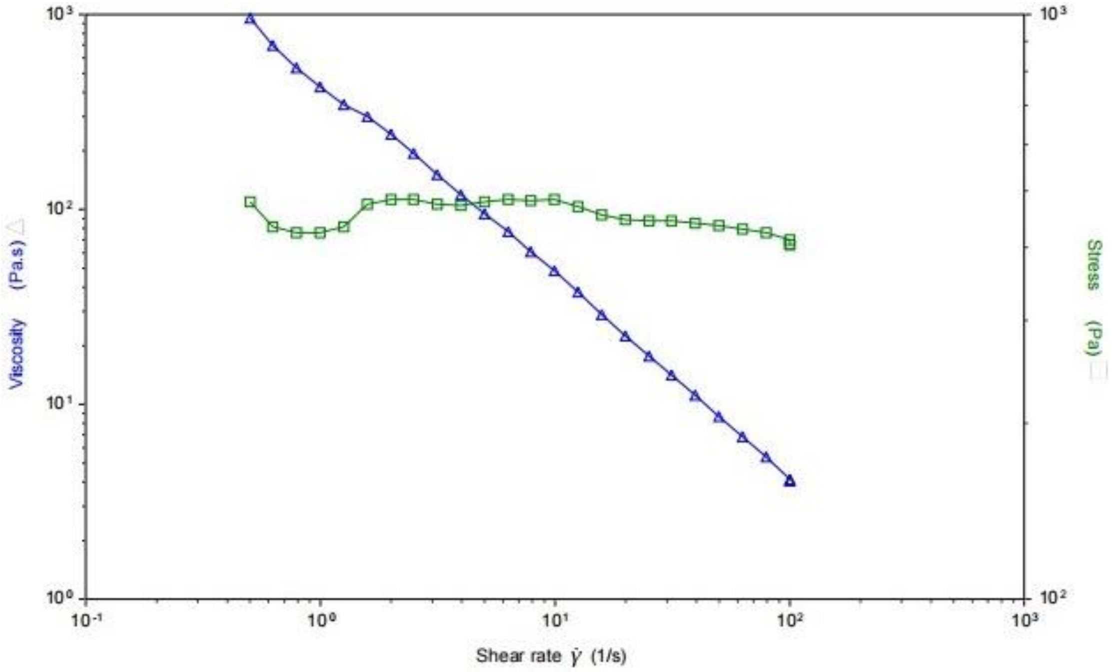


Fig. 17. Rheometer results of peanut ink after radiated with 1.5 kGy of Gamma rays

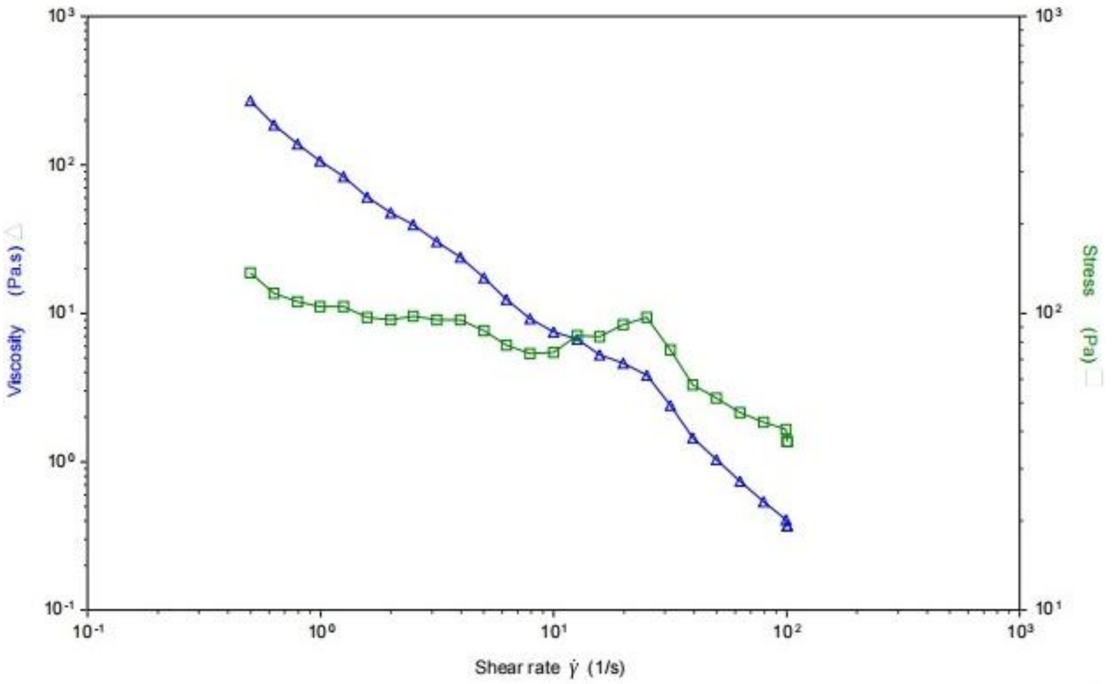


Fig. 18. Rheometer results of soybean ink after radiated with 1.5 kGy of Gamma rays

After the radiation treatment with 2.0 kGy of gamma rays settled, the stress curve from the peanut ink graph increased at point 5 with the viscosity of 224.4 Pa.s. before decreasing back into line (Figure 19). There were differences in the shear rates that happened between points 4 and 5, which varied from 0.9 in 1/s to 1.2 in 1/s. The dissimilar value indicated that the pressure given increased the potential of interaction between the surface and the sample, which in this case was peanut ink. The intersection link occurred at point 14, and the measured viscosity at the crossing point was at 32.4 Pa.s. As for the soybean ink, the cross-linking occurred between points 15 and 16. Thus, the range was at intervals of 2.0 Pa.s to 1.7 Pa.s. The decreasing stress line for the soybean ink graph (Figure 20) was not smooth compared to the peanut ink. The stress line continued to decrease until it reached point 8. It then gradually grew and created an upward curve in time until point 21. At point 21, the stress rose from 24.8 Pa.s to 26.1 Pa.s at point 24, which declined the viscosity from both points. As a result, a sudden increase in pressure occurred at both points 24 and 25, resulting in a greater drop in viscosity.

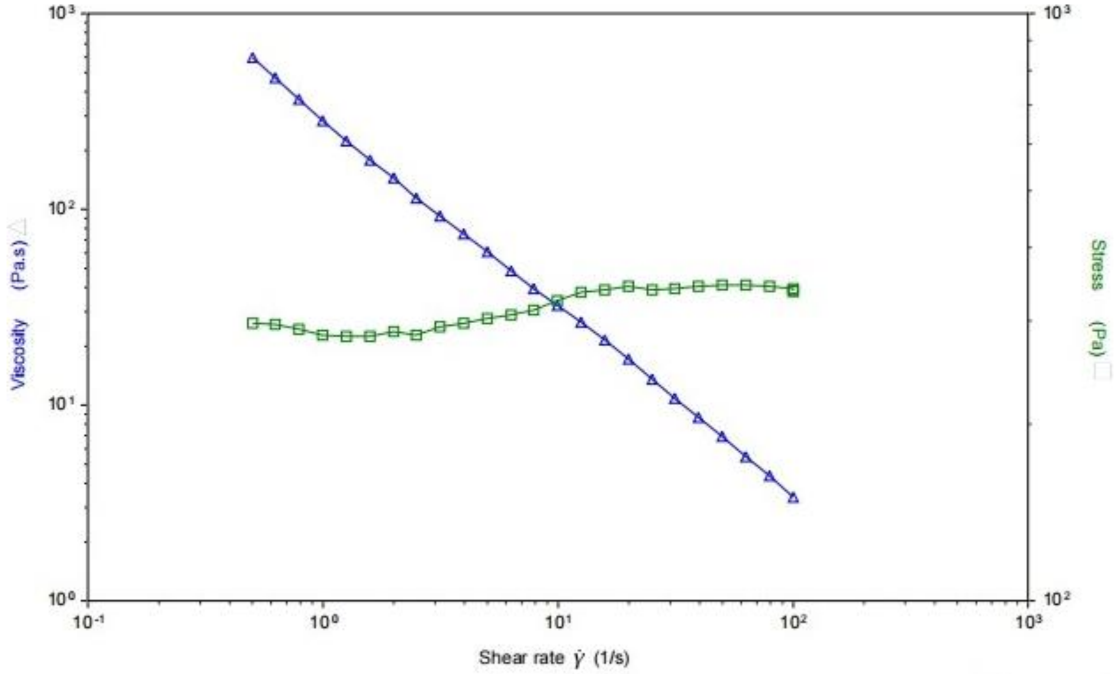


Fig. 19. Rheometer results of peanut ink after radiated with 2.0 kGy of Gamma rays

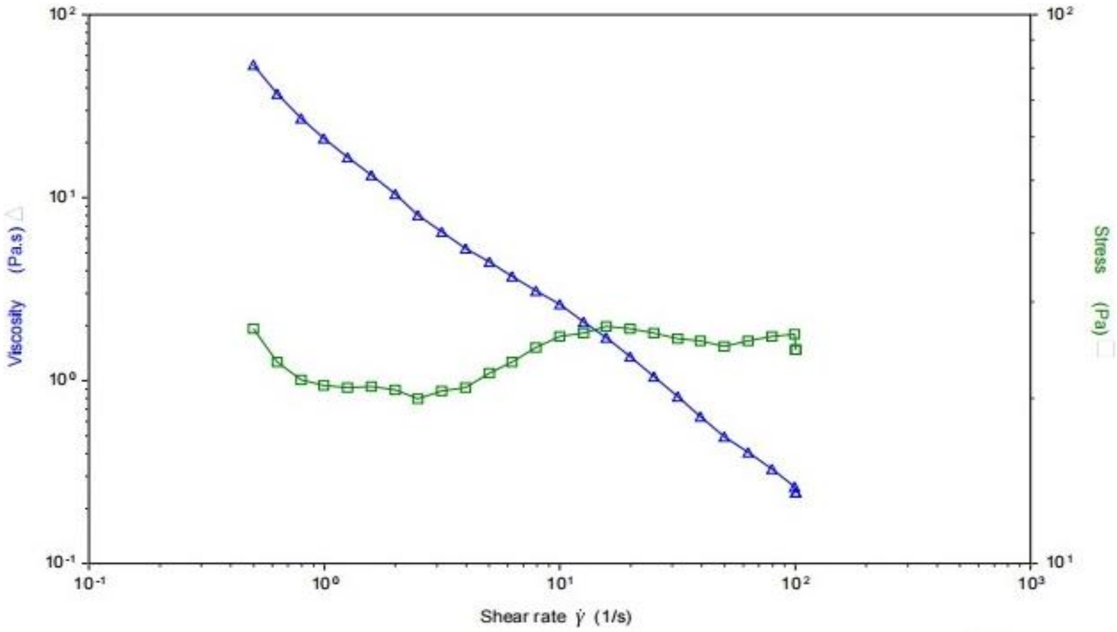


Fig. 20. Rheometer results of soybean ink after radiated with 2.0 kGy of Gamma rays

Lastly, for radiation treatment of 2.5 kGy of gamma rays, the peanut ink graph showed that the viscosity recorded was at 44.3 Pa.s because the stress curve brought the plots to intersect at point 13. The decreasing viscosity and stress given could be classified as a smooth graph (Figure 21). The stress curve for the soybean ink graph was made into an upward curve, which meant that the stress given increased rather than decreased before returning to point 25 (Figure 22). However, a cross-linking phase happened at point 10 with the viscosity of 1.2 Pa.s.

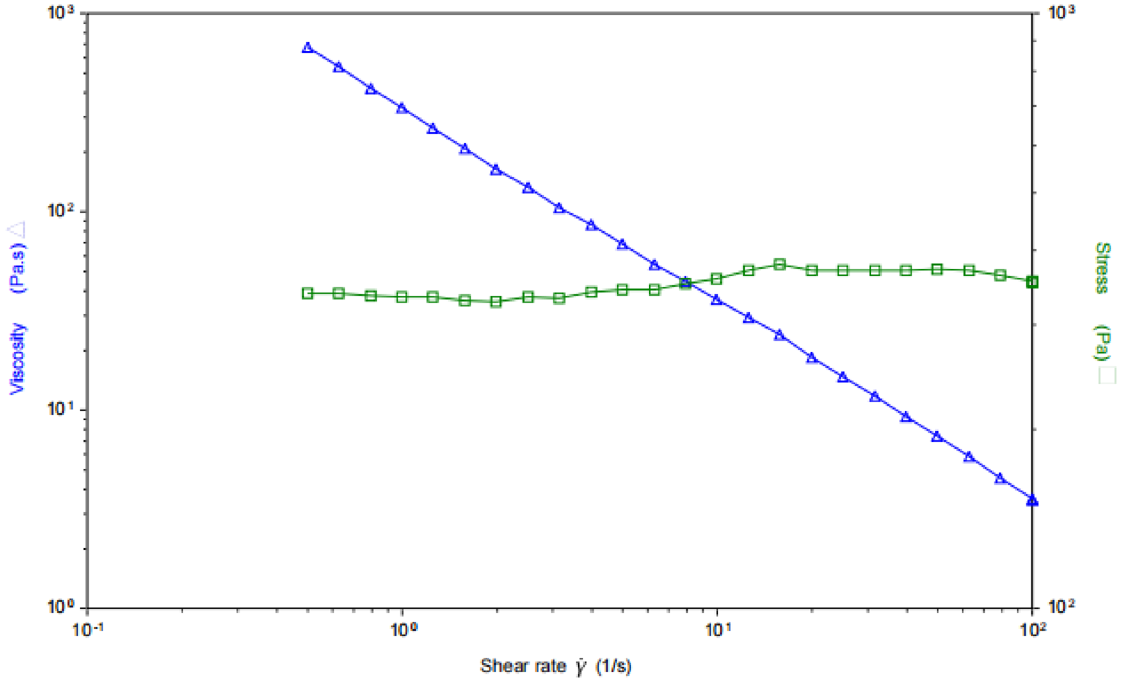


Fig. 21. Rheometer results of peanut ink after radiated with 2.5 kGy of Gamma rays

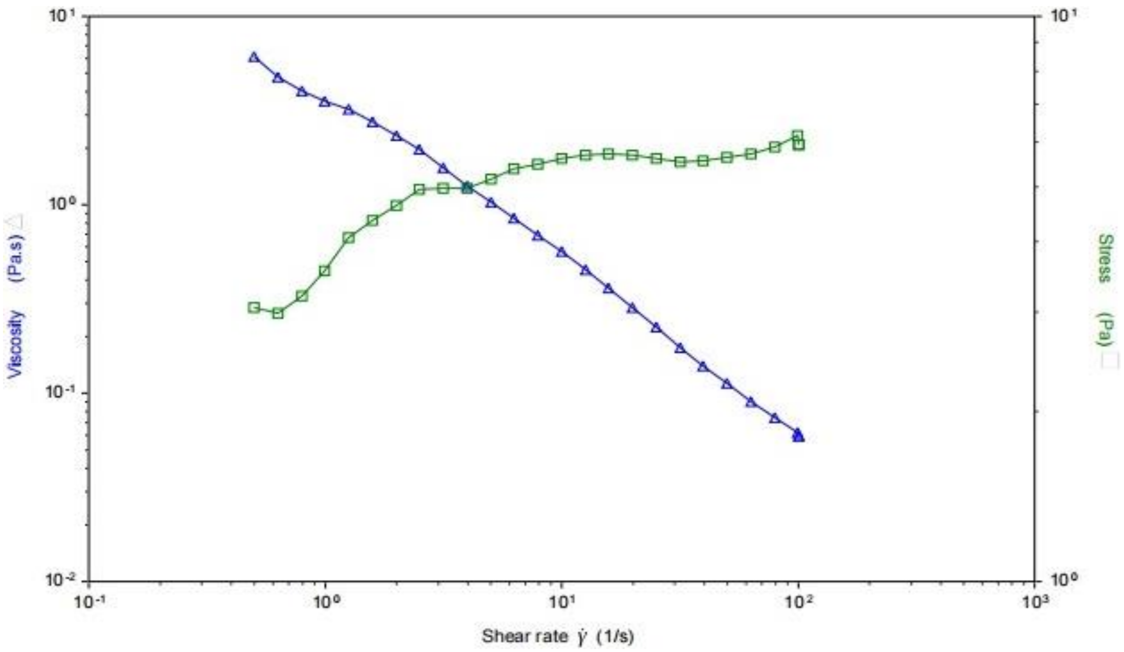


Fig. 22. Rheometer results of soybean ink after radiated with 2.5 kGy of Gamma rays

Overall, the viscosity of peanut ink improved significantly after undergoing radiation treatments, which differed from soybean ink. Both pre- and post-conditions showed that the viscosity increased. The best radiation dose that resulted in a higher viscosity reading was 1.5 kGy of gamma rays. It fluctuated the value of viscosity reading more than the other four rays and even more than the result of pre-radiation treatment. The thixotropy quality of both inks influenced the change in viscosities. Thixotropy quality is a condition where the state of liquids or gels is of high viscosity under normal temperature and turns them into a flow state when exposed to pressure or agitated. It makes it very easy for the mixture to slide together. It is a rheological characteristic that liquid or semi-solid samples may have [18]. The longer a sample comes across stress, the lesser its viscosity becomes. Some of the samples may return to their normal states after a long time and some may return after the pressure is removed. However, some liquids do not change their flow conditions, instead, they become harder and acquire higher viscosities.

Viscosity is influenced by thixotropic qualities because the ink will be in a semi-liquid or gel state and has a high viscosity before it is used. It becomes less viscous when a force or pressure is applied to it. The print quality is also affected since the ink would not produce a clear half-tone point on the surface. Through the graphs, the rheological and viscosities of both inks changed after the radiation treatment [6,23]. The higher the energy of rays emitted, the higher the changes in viscosities occurred [22,24,25]. These conditions affected the peanut ink, as its viscosity increased as a result of the radiation process. The soybean ink also showed an increase in its viscosity value after being radiated. Higher viscosities provided better adhesiveness of ink towards any surface and did not easily flow or melt.

4. Conclusion

The examined outcomes showed the difference between the inks. The size, color, smell, and time to heat the beans varied from each other. The peanut ink is a non-drying oil that requires the addition of resins to cooperate with the viscosity and hardness of the ink when applied. Due to the oxidation process, drying oils (such as the soybean ink) reach a semi-liquid phase sooner when exposed to their surroundings. The results of testing using FTIR and rheometer machines showed changes in the organic and inorganic groups (that were present in both inks) after the radiation treatment with different values from before treatment. Overall, the intensity of peanut ink was better than soybean ink and this high intensity helps in producing a better color of ink with fewer dots on the surface. The rheological changes in rheometer results were also evaluated for both inks. In general, the viscosity of the ink changed between pre- and post-radiation. The post-treatment resulted in a high increase in viscosity compared to pre-treatment, due to the amount of stress or force applied to the samples. The peanut ink could withstand changes in pressure or temperature without leaving a lot of smudges when used on paper. Therefore, peanut ink is more suitable for consumer usage.

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