Foaming performance test of palm oil foaming agent solution for prevention and fire extinguishing on peatland surface

G Pramuhadi1, M Rivai2, E Hambali2,3, and A Suryani2,3

1 Department of Mechanical and Biosystem Engineering, IPB University, Indonesia
2 Surfactant and Bioenergy Research Center (SBRC), IPB University, Indonesia
3 Department of Agroindustrial Technology, IPB University, Indonesia

* Corresponding author: gpramuhadi@apps.ipb.ac.id

Abstract. This research aims to test the performance of palm oil foaming agent solution (POFAS) in a laboratory for the prevention and fire extinguishing of a peatland surface. The materials used in this research were POFAS formulas, i.e. NF45 and NF46, at various concentrations of 1%, 2%, 3%, and 6%. Measuring tools and machines used were patternator and spraying measurement tools, a knapsack mist blower for the foam method, a knapsack electric sprayer, and an air blower for the non-foam method. Results of this research showed that the minimum droplet diameter, maximum droplet density, maximum effective spraying width, and minimum effective spraying debit were 452.06 μm, 136.22 droplets cm⁻², 72 cm, and 1.47 liter min⁻¹ for foam method, and 452.24 μm, 148.33 droplets cm⁻², 56 cm, and 1.84 liter min⁻¹ for non-foam method. In the foam method, the NF45 formula with a concentration of 2% was the most effective POFAS formula for the prevention and extinguishing of the peatland surface because it has the largest ability to cover the peat surface pore spaces. In the non-foam method, the NF46 formula with a concentration of 3% was the most efficient POFAS formula because it has a large effective spraying width and the smallest effective spraying debit so that this POFAS application was the shortest and most efficient in POFAS consumption.

1. Introduction

GAPKI [1] reported that in Indonesia, there are 14.9 million hectares of peatlands and 11.4 million hectares of oil palm plantation areas. About 10% (1.5 million hectares) of peatland areas are used for oil palm plantation. It is shown in NASA Active Fire Data that in November 2015, about 7% (0.80 million hectares) of palm oil plantation areas were burned. Consequently, intensive handling to overcome fire in peatland areas is required. This can be done by applying a palm oil-based foaming agent, which has suitable characteristics for a fire extinguisher.

A foaming agent is a surfactant that reduces surface tension and interfacial tension, forms a foam, and maintains foam stability. The use of surfactants in a foaming agent increases the effectiveness of water utilization and improves the performance of the foaming agents in extinguishing the fire. Surfactant functions in a foaming agent are as a surface tension reducer and a foaming agent [2].

Foaming agent concentrate from palm oil is developed for type A fire involving solid materials excluding metal. In a fire extinguisher application, a foaming agent facilitates the formation of foam when the agent is dissolved in water in low concentration. The resulted foam cools down the fire, covers the burned materials, inhibits the spread of smoke, avoids re-contact with oxygen which can reignite fire, and improves the efficiency of water use. In addition, to increase the added value, the use
of palm oil as a foaming agent reduces the dependency on imported foaming agent products and supports the diversification of downstream palm oil products.

In general, it is known that the cause of the fire is the conspiracy of energy, fuel, and oxygen (fire triangle) as depicted in Figure 1.a. The energy can be in the form of high temperatures which can start a fire such as high environmental temperature as a result of the scorching sun in the dry season, lightning bolt, or volcanic activities (lava flow or hot clouds). In addition, peat fires can also be caused by human carelessness, new peatland opening, land clearing for agricultural or plantation areas by using fire [3], or other causes including underground fire. Fires in peatland can also start if there are coals or fire under the ground. Fires in peatland are illustrated in Figure 1.b.

![Fire Triangle](image1a.png)

**Figure 1.** (a) Fire triangle (the conspiracy of energy, fuel, and oxygen) [4] and (b) illustration of fires in peatland [5]

As shown in Figures 1, the effort in extinguishing fires in a peatland can be done by annihilating or eliminating one of the fire causes by avoiding contact between fuel and oxygen. This can be done through the application of a foaming agent by using a fire-fighting device as shown in Figure 2.

![Fire Fighting Device](image1b.png)

**Figure 2.** The use of a fire-fighting device for fire extinguisher [6]

In a peatland, fire extinguishments can be done at the low-level fire. The method that can be introduced is the application of a foaming agent by using a device to transform the foaming agent solution into foaming agent droplets by utilizing spraying devices in a laboratory. The devices are sprayers that can spray foaming agent in the form of foam and non-foam. An example of a sprayer that
can apply the foaming agent in the form of foam is a knapsack mist blower, whereas a knapsack electric or battery sprayer and an air blower can apply the foaming agent in the form of non-foam.

Efforts to prevent and extinguish fires in peatlands can be achieved by covering the peatland surface so that there is no contact between fuels, sources of heat energy (fire coals), and oxygen. The material of peat surface cover is in the form of palm oil foaming agent solution (POFAS) which has suitable characteristics for fire fighting. Some research must be conducted in a laboratory before the POFAS formulas can be applied to the field. The POFAS formulas are applied in the form of foam and non-foam droplets utilized in a knapsack mist blower, a knapsack electric sprayer, and an air blower which are sprayed onto the surface of a patternator in a laboratory. Therefore, the objective of this research is to test the POFAS formulas in a laboratory to determine the parameters of POFAS performances.

2. Materials and methods
The research was conducted from January to March 2019 at the Protection Machinery and Equipment Laboratory, Leuwikopo, IPB University Darmaga Campus, Bogor, Indonesia to determine the parameters, i.e. droplet diameter, droplet density, effective spraying width, and effective spraying debit. The materials used in this research were POFAS formulas, i.e. NF45 and NF46, at various concentrations of 1%, 2%, 3%, and 6%. Measuring instruments and machines used were patternator, protractor, scanner, measuring cup, stopwatch, concord papers, spraying devices, i.e. a knapsack mist blower TASCO MD-150 for foam method, and a knapsack electric sprayer POLAR E-16A and an air blower BOOSTER for non-foam method, and a computer. Spraying devices used in this research are shown in Figure 3. Determination of optimum POFAS performance was based on the ability of the sprayers to produce minimum droplet diameter, maximum droplet density, maximum effective spraying width, and minimum effective spraying debit.

![Figure 3](image)

Figure 3. A knapsack mist blower, a knapsack electric sprayer, and an air blower that is used in this research

Determination of foaming effectiveness and efficiency parameters of POFAS is important to be done before it is applied in fire extinguishments. In principle, fire extinguishments are covering or filling a surface and porous space with POFAS to avoid contact between oxygen and fire or coals of fire so that the fire or coals of fire can be extinguished.

Fire extinguishments using POFAS will be more effective with finer droplet size (droplet diameter) and higher droplet density. Efficient fire extinguishment is also important in order to save time and money. This can be achieved with quick and cheap POFAS applications. In order to achieve it, no repeated application is advised, droplet distribution during the application time is done once, and the
volume of droplets applied is not excessive. This condition is met if the effective spraying width (ESW) is high and effective spraying debit (ESD) is low (economical). In other words, fire extinguishments will be more efficient (short application time and economical application cost) if ESW is high and ESD is low.

Determination of optimum (effective and efficient) fire extinguishment was based on the most effective and the most efficient foaming test results. The flow chart of this analysis is shown in Figure 4.

Figure 4. An analytic chart for determining optimum fire extinguishment by using POFAS

It was shown that the determination of optimum (effective and efficient) POFAS application for fire extinguishments was based on minimum droplet diameter, maximum droplet density, maximum effective spraying width (ESW), and minimum effective spraying debit (ESD). These four parameters of foaming effectiveness and efficiency can be measured at the Laboratory of Protection Machinery and Equipment, Leuwikopo, IPB Darmaga Campus, Bogor as shown in Figure 5.

Figure 5. Sample activity in the determination of optimum POFAS foaming

The determination of the four parameters was based on the droplet spreading on a patternator. Liquid volume accommodated in each measuring cup, spraying angle, and spraying time was measured to determine the effective spraying width (ESW) and the effective spraying debit (ESD) as seen in Figure
6. Determination of spraying angle and effective spraying width (ESW) will produce effective spraying distance. Based on the value of the effective spraying distance, it can be used to determine droplet diameter and droplet density by using concord papers, a scanner, and a computer.

Figure 6. Determination of the four parameters in the Laboratory of Protection Machinery and Equipment

Effective spraying width (ESW) was determined by replacing an original spraying pattern on several overlapping patterns. ESW was determined by calculating the coefficient of variation (CV) of each overlapping pattern. Finally, ESW can be calculated by determining the minimum CV and the measure distance from both of two cross-sections as seen in Figure 7.

Figure 7. An example of effective spraying width determination

Effective spraying debit (ESD) was determined by calculating the total volume accommodated in each measuring cup on the range of effective spraying width (ESW). ESD can be calculated by calculating the volume accommodated divided by spraying time.
Droplet diameter and droplet density were determined by using an image processing program, which is made using “C-Language” of SharpDevelop 4.3 software. The determination process can be seen in Figure 8.

![Diagram of determination process](image)

**Figure 8.** The determination process of droplet diameter and droplet density

Firstly, the POFAS with several concentrations mixed with dark ink, and then it is sprayed onto concord paper surface perpendicular with droplet spraying direction from the nozzle on its effective spraying distance. Scan and crop the 10 cm x 10 cm droplet picture, then conduct a major binary of it to determine the total area of paper and the total area of the droplet. Conduct a minor binary to determine the area of one droplet. Output data from the program is an area in the unit of pixel.

Secondly, the output data are processed to determine droplet diameter (unit: micron meter) and droplet density (unit: droplet cm$^{-2}$).

### 3. Results and discussion

Results of foaming performance test of POFAS showed that at a constant pressure of 7.0 kgf cm$^{-2}$ in average and effective spraying height of 40-63 cm, so it can be notified that droplet diameter, droplet density, effective spraying width, and effective spraying debit varied at various POFAS formulas (NF45 and NF46) and concentrations (1%, 2%, 3%, and 6%) as seen on Table 1. The results showed that in the top performance condition of sprayers, it was obtained minimum droplet diameter and maximum droplet density of 452.06 µm and 136.22 droplets cm$^{-2}$ for foam method, and 452.24 µm and 148.33 droplets cm$^{-2}$ for non-foam method.

The most effective POFAS for the prevention and extinction of peat surface fires was obtained at NF45 formula with a concentration of 2% because it produced the best minimum droplet diameter and maximum droplet density for both, foam method and non-foam method. POFAS formula of NF45 with a concentration of 2% had a union between water particles and POFAS in producing the minimum size of the droplet and maximum droplet quantity per unit area so that it has the largest ability to cover the peat surface pore spaces. The droplet distribution pattern of the NF45 formula with a concentration of 2% is shown in Figure 9.

The maximum effective spraying width of 72 cm was obtained at NF45 formula 1% and NF46 2% concentrations for the foam method, and 56 cm for the non-foam method at NF45 formula.
concentrations of 1% and 6% as well as NF46 formula concentrations of 1% and 3%. The minimum effective spraying debit of 1.47 liters/minute was obtained at NF45 formula concentration 3% for foam method and 1.84-liter min\(^{-1}\) at NF46 formula 3% for non-foam method.

Table 1. Results of POFAS performance test

| Method                   | POFAS formula | POFAS concentration (%) | Performance parameters | Droplet density (droplet cm\(^{-2}\)) |
|--------------------------|---------------|-------------------------|------------------------|--------------------------------------|
|                          |               |                         | ESW (cm)               | ESD (litre min\(^{-1}\))              |
| Foam (mist blowing)      | NF45          | 1                       | 72                     | 1.95                                 |
|                          |               | 2                       | 64                     | 1.85                                 |
|                          |               | 3                       | 64                     | 1.47                                 |
|                          |               | 6                       | 64                     | 1.66                                 |
|                          | NF46          | 1                       | 64                     | 1.54                                 |
|                          |               | 2                       | 72                     | 1.94                                 |
|                          |               | 3                       | 64                     | 1.84                                 |
|                          |               | 6                       | 64                     | 1.59                                 |
|                          | Non-foam      | NF45                    | 1                       | 56                                   |
|                          |               |                         | 2                       | 48                                   |
|                          |               |                         | 3                       | 48                                   |
|                          |               |                         | 6                       | 56                                   |
|                          | NF46          | 1                       | 56                     | 2.42                                 |
|                          |               | 2                       | 48                     | 2.22                                 |
|                          |               | 3                       | 48                     | 2.53                                 |
|                          |               | 6                       | 56                     | 2.48                                 |

Note: POFAS: palm oil foaming agent solution; ESW: effective spraying width; ESD: effective spraying debit

In the non-foam method, the NF46 formula with a concentration of 3% was the most efficient POFAS because it has a large effective spraying width and the smallest effective spraying debit. POFAS formula of NF46 with a concentration of 3% had a union between water particles and POFAS in spreading droplet widely and minimum POFAS application per unit of time so that the POFAS application will be the shortest and most efficient in POFAS consumption.

Figure 9. An example of the droplet distribution pattern of NF45 formula with a concentration of 2%
The difference in the result above (Table 1) is caused by the difference in spraying mechanism between the two methods i.e. the foam method utilized a knapsack mist blower and the non-foam method utilized an electric sprayer and an air blower as seen in Figure 10. On the foam method, there was a very high-speed rotation of blower shaft that will produce a high-speed airflow, so that it can push the POFAS crash the nozzle vanes surfaces to become a droplet. On the non-foam method, the POFAS is exited from the liquid tank caused by a high-pressure solution from a liquid pump, which it resourced from a battery. Furthermore, the high-pressure solution of POFAS from the liquid pump will be sucked and blown by a blower (air blower), and then it is directed by air blower nozzle in the form of droplet toward a sprayed area.

**Figure 10.** A schematic spraying mechanism of foam method (a) and non-foam method (b)

Based on Table 1, it looked that the foam method had advantages in larger ESW and smaller ESD than the non-foam method, but it had a deficiency in producing droplet density than the non-foam method. So, it can be recommended to improve the foam method of POFAS application by replacing its nozzle vanes number as seen in Figure 11.

**Figure 11.** Sample of several nozzle vanes that can be paired on knapsack mist blower nozzle
4. Conclusion
It was determined that the NF45 formula with a concentration of 2% was the most effective POFAS application for the prevention and extinction of peat surface fires because it has the largest ability to cover the peat surface pore spaces. In the non-foam method, the NF46 formula with a concentration of 3% was the most efficient POFAS application because it has a large effective spraying width and the smallest effective spraying debit so that this POFAS application was the shortest and most efficient in POFAS consumption.

5. References
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