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Article

A Study on the Effectiveness of Various Concentrations of Clove Flower Extract (Syzygium aromaticum) in Reducing the Peroxide Value of Used Cooking Oil

Della Oktavia, Nurul Amaliyah, Nuryanto

Department of Environmental Health, Poltekkes Kemenkes Semarang, Purwokerto, Indonesia.

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Abstract
The repeated use of cooking oil in the frying process can accelerate lipid oxidation and reduce the quality of the oil; therefore, an approach is needed to inhibit this oxidative process. Clove flowers (*Syzygium aromaticum*) contain bioactive compounds with antioxidant activity that have the potential to be used to reduce oil oxidation. This study aimed to analyse the effectiveness of various concentrations of clove flower extract in reducing the peroxide value of used cooking oil obtained from fried food vendors in the Baturraden area. The study employed apost-test-only control group experimental design with five treatment groups: a control group without extract and groups with clove flower extract added at various concentrations, with six replicates in each group. The clove flower extract was prepared using the maceration method with 70% ethanol, whilst the peroxide value was determined using the iodometric titration method. The data were analysed using the Shapiro–Wilk test, the homogeneity test, One-Way Analysis of Varianc*e*, and Tukey's test. The results showed that the addition of clove flower extract resulted in a greater reduction in the peroxide value as the concentration increased. Comparisons between groups revealed that some concentrations produced a significant reduction compared with the control, whilst the lowest concentration did not yet show a significant difference. The treatment also affected the organoleptic characteristics of the oil. Clove flower extract has the potential to be used as a natural source of antioxidants to inhibit the oxidation of used cooking oil; however, further research is required regarding safety, stability, characterisation of bioactive compounds, and optimal conditions for use.

Corresponding Author:

Della Oktavia
Department of Environmental Health, Polytechnic Ministry of Health Semarang, Purwokerto, Indonesia
Email: dellaoktavia2010@gmail.com

Introduction

Oxidation of oils can generally be controlled through the use of antioxidants capable of inhibiting oxidative reactions. Interest in natural antioxidants is growing because bioactive compounds from plants have the potential to be used as alternatives for maintaining the oxidative stability of oils. One relevant source is cloves (*Syzygium aromaticum*), which contain phenolic compounds, eugenol, flavonoids, and tannins. These compounds possess antioxidant activity that, in theory, can inhibit the formation of free radicals and suppress lipid oxidation. A number of studies have shown that components of cloves can improve the oxidative stability of oils and reduce the formation of oxidation products. Previous research has also explored the use of clove oil or extracts in various types of oils, including edible oils and vegetable oils, thereby providing a scientific basis for the potential of cloves as a source of natural antioxidants.

However, evidence regarding the effectiveness of cloves on used cooking oil specifically derived from fried food vendors remains limited, particularly regarding the peroxide value response across different extract concentration ranges. Existing research has primarily focused on the effects of repeated use on oil quality degradation or the ability of cloves to improve the oxidative stability of oil in general. Thus, further experimental data is needed to demonstrate whether increasing concentrations of clove flower extract consistently result in a reduction in the peroxide value of used cooking oil that has undergone real-world usage conditions. In addition to chemical aspects, changes in the oil's organoleptic characteristics following the addition of the extract must also be considered, as the effectiveness of a treatment is determined not only by its ability to reduce oxidation indicators but also by the physical characteristics of the resulting oil. This paper therefore proposes testing several extract concentrations as an approach to understanding the relationship between treatment concentration, the reduction in the peroxide value, and changes in the oil's organoleptic characteristics.

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Based on this gap, this study aims to analyze the effectiveness of various concentrations of clove flower extract (*Syzygium aromaticum*) in reducing the peroxide value of used cooking oil obtained from fried food vendors in the Baturraden area. This study also evaluates changes in the oil's organoleptic characteristics after treatment with the extract at different concentrations, thereby providing a basis for assessing the effectiveness of the treatment not only based on oxidation parameters but also on the oil's physical characteristics..

Cooking oil is one of the food ingredients widely used in food processing, particularly in foods prepared by frying. The habit of consuming fried foods remains widespread amongst the public because they are readily available, affordable and have a flavour that is widely enjoyed. However, the frying process, involving the repeated use of oil, can lead to a deterioration in the oil's quality, both physically and chemically. Damage to the oil caused by repeated heating is characterised by a darker colour, a rancid odour, increased viscosity, and the formation of oxidation by-products such as peroxides and aldehydes, which can compromise food safety [1]–[3]. The peroxide value is an important parameter for assessing the degree of oil deterioration, as a high value indicates that the oil has undergone oxidation. According to SNI 01-3741-2013, the maximum peroxide value for cooking oil is 10 meq O_2/kg; therefore, oil with a peroxide value exceeding this limit indicates a decline in quality and does not meet the quality requirements for cooking oil [4], [5].

Research on fried food vendors along Baturraden Highway also showed that all oil samples, after being used three times, failed to meet SNI standards as they had a peroxide value exceeding 10 meq O_2/kg [6]. This situation indicates that the repeated use of cooking oil by fried food vendors has the potential to cause food safety issues and requires attention. One way to slow down the oxidation of oil is to use natural antioxidants. Clove flowers (Syzygium aromaticum) are a natural source of antioxidant compounds such as eugenol, flavonoids, tannins and phenolic compounds. These compounds help to inhibit lipid oxidation by scavenging free radicals and suppressing the formation of peroxide compounds[3]. The addition of clove oil as a natural antioxidant has been shown to reduce the peroxide value in cooking oil [7].

Based on the above, this study aims to analyse the effectiveness of various concentrations of clove flower extract (Syzygium aromaticum) in reducing the peroxide value of used cooking oil from fried food vendors in Baturraden in 2026. It is hoped that the results of this study will provide information on the potential use of clove flowers as a natural antioxidant to help reduce oxidative damage in used cooking oil.

Materials and Method

Research Design and Approach: This study is a laboratory experiment using a post-test-only control group design. The study was conducted to evaluate the effect of adding clove flower extract (*Syzygium aromaticum*) at various concentrations on the peroxide value of used cooking oil obtained from fried food vendors in the Baturraden area. Used cooking oil was used as the test material as it had undergone repeated use, resulting in a decline in its oxidative quality. The treatments consisted of one control group without the addition of extract and four groups to which clove flower extract was added at concentrations of 0.06%, 0.08%, 0.5% and 1%. Each treatment group was replicated six times.

Samples of Used Cooking Oil: The research samples consisted of used cooking oil obtained from vendors selling fried foods in the Baturraden area. The selection of sample sources was based on the criteria that vendors reused cooking oil more than three times, operated roadside stalls, and used tofu or tempeh as the main ingredients for frying. The oil obtained from vendors meeting these criteria was then collected and homogenised before being used in the treatments. Homogenisation was carried out to obtain a relatively uniform oil sample before it was divided into control and treatment groups.

Production of Clove Flower Extract: The plant material used was dried clove buds (*Syzygium aromaticum*). The clove buds were first cleaned to remove any impurities and then ground using a blender until a powder was obtained. The clove flower powder is placed in an Erlenmeyer flask and 70% ethanol is added in a 1:2 ratio of material to solvent. The flask is sealed tightly and stored in a place protected from direct light. The maceration process is carried out for five days, with stirring for 15 minutes each day at the same time. Once the maceration process was complete, the mixture was filtered through filter paper to obtain the filtrate. The filtrate was then evaporated using a rotary evaporator to obtain a concentrated extract. This extract was subsequently dissolved in 100 mL of distilled water and used to prepare treatment solutions at the specified concentrations.

Treatment of Extracts in Used Cooking Oil: The homogenised used cooking oil was divided into five groups: a control group and four treatment groups. The control group was not treated with clove flower extract, whilst the treatment groups were treated with the extract at concentrations of 0.06%, 0.08%, 0.5% and 1%. Each group comprised six replicates. After treatment, oil samples were used to measure the peroxide value and assess organoleptic characteristics. Multiple concentrations were used to compare changes in the peroxide value at different extract concentrations and to determine the concentration that resulted in the greatest reduction in the peroxide value.

Measurement of Peroxide Value: The peroxide value is used as the primary parameter for assessing changes in the oxidation level of the oil following treatment. Measurements were carried out using the iodometric titration method in accordance with SNI 3741:2013. A total of 5 g of oil sample from each group was weighed and placed into a 250 mL Erlenmeyer flask. Acetic acid–chloroform mixture in a 3:2 ratio and a 15% potassium iodide (KI) solution were then added to the sample, which was gently shaken until homogeneous. Distilled water was then added before titration was carried out using a 0.01 N sodium thiosulphate ($Na_2S_2O_3$) solution. Titration was carried out until the yellow colour of the solution faded, after which a 1% starch indicator was added and titration continued until the blue colour disappeared. The volume of sodium thiosulphate used is recorded and used to calculate the peroxide value based on the difference in titrant volume between the sample and the blank.

Observation of Organoleptic Characteristics: The organoleptic characteristics of the oil were observed as supporting parameters to describe the physical changes in the oil following the addition of clove flower extract. Observations included the colour, aroma and clarity of the oil in both the control and treatment groups. The colour of the oil was categorised based on changes in visual appearance, whilst the aroma was assessed to determine the presence of rancid odours or the characteristic clove aroma. Clarity was assessed based on the visual condition of the oil and the presence of sediment following treatment. The results of the organoleptic observations were used as supporting information when evaluating the characteristics of the oil at each extract concentration.

Data Analysis: The data from the peroxide value measurements were analysed statistically to determine differences in values between the treatment groups. The Shapiro–Wilk test was used to assess the data distribution, whilst a homogeneity test was used to assess the equality of variances between groups. Once the requirements for parametric analysis had been met, differences in peroxide values between the control group and the treatment groups were analysed using a one-way analysis of variance (ANOVA) at a significance level of 5% ($\alpha = 0.05$). Where significant differences were found between groups, the analysis was continued using Tukey's test to identify which treatment groups differed significantly. In addition to the analysis of differences, the effectiveness of the reduction in peroxide value at each concentration compared with the control group was calculated and presented as a percentage.

Results

Peroxide Value Measurement Results

The results of the analysis showed a decrease in the peroxide value as the concentration of clove flower extract increased. The control group had the highest average peroxide value, at 14.16 meq/kg, whilst the 1% concentration had the lowest average, at 1.5 meq/kg. According to Table 1, concentrations of 0.08%, 0.5% and 1% were able to reduce the average peroxide value to below the maximum limit specified in SNI 01-3741-2013, namely 10 meq O_2/kg. A concentration of 0.06% only reduced the value to 12.6 meq/kg, and therefore still did not meet the SNI requirements. The highest efficacy was observed at a concentration of 1%, namely 89.4%.

Table 1. Results of Peroxide Value Analyses Following the Addition of Clove Flower Extract

Treatment	Average Peroxide Value	Effectiveness
Control	14.16 meq/kg	-
0.06%	12.6 meq/kg	11%
0.08%	9.5 meq/kg	33%
0.5%	5.7 meq/kg	60%
1%	1.5 meq/kg	89.4%

Organic Results

Organoleptic assessments were carried out to evaluate the colour, aroma and clarity of the oil following treatment. The control group exhibited a dark brown colour, a rancid aroma and a cloudy appearance. In the treatment groups, the oil tended to be lighter in colour and the rancid aroma was reduced, particularly at concentrations of 0.5% and 1%.

Table 2. Organoleptic Properties of Used Cooking Oil

Treatment	Organoleptic Result
Control	Dark brown, rancid, cloudy
0.06%	Dark brown. rancid. cloudy
0.08%	Yellowish brown. rancid. cloudy
0.5%	Yellow. faint clove aroma. clear
1%	Yellow. moderate clove aroma. clear. with some sediment

These organoleptic changes indicate that clove flower extract not only plays a chemical role but also affects the physical characteristics of the oil. However. a 1% concentration produced a moderate clove aroma and sediment; therefore. a 0.5% concentration may be considered a better alternative in terms of physical acceptability. as the peroxide value is already below the SNI standard and the clove aroma is weaker.

Statistical Analysis

The results of the Shapiro-Wilk normality test for all groups showed a p-value > 0.05. indicating that the data are normally distributed. The homogeneity test yielded a p-value of 0.203. indicating that the data are homogeneous. The results of the one-way ANOVA showed p=0.001 (0.05). meaning that there was a difference in peroxide value across the various concentrations of clove flower extract. Tukey's test showed that the concentrations of 0.08%. 0.5% and 1% differed significantly from the control. whilst the concentration of 0.06% did not differ significantly from the control (p=0.415).

These findings indicate that an extract concentration that is too low is insufficient to produce a significant reduction in the peroxide value. Conversely. increasing the extract concentration increases the amount of antioxidant compounds available to inhibit lipid oxidation reactions. The phenolic compounds in cloves can donate hydrogen atoms to stabilise free radicals. thereby suppressing the formation of hydroperoxides as primary oxidation products [8]–[10].

Discussion

The results of the study indicate that used cooking oil obtained from fried food vendors in the Baturraden area had already undergone oxidative degradation prior to treatment. This condition is indicated by the peroxide value of the control group, which exceeded the quality limit used in the study—namely, 10 meq O_2/kg based on SNI 3741:2013—and is supported by organoleptic characteristics such as dark color, a rancid odor, and a cloudy appearance. These findings indicate that the repeated use of oil in the frying process is associated with increased lipid oxidation. These results are consistent with studies on oil used by fried food vendors in other regions, which showed that repeated heating leads to an increase in the peroxide value and a decline in the oil's physicochemical quality and antioxidant capacity.[11]. Previous research on fried food vendors in the Baturraden area also reported that the repeated use of oil is associated with an increase in the peroxide value to levels exceeding quality standards [4]. Thus, the condition of the oil in the control group in this study indicates that oil that has been reused requires attention from a quality control perspective before it is reused in food processing.

Chemically speaking, repeated heating can accelerate lipid oxidation because the oil is repeatedly exposed to high temperatures and oxygen during the frying process. This reaction produces free radicals that can trigger the formation of hydroperoxides as primary oxidation products [12]. The peroxide value is one of the parameters used to characterize the presence of primary oxidation products in oil; therefore, an increase in this value can serve as an indicator of lipid oxidation in its early stages [13]. However, hydroperoxides are relatively unstable compounds and can undergo further decomposition into secondary oxidation products, including various aldehydes [14]. Therefore, the peroxide value in this study is best understood as an indicator of primary oxidation and does not yet fully reflect the overall degree of oil degradation. A more comprehensive assessment of oxidation in future studies could combine the peroxide value with secondary oxidation parameters, such as the *p-anisidine value*, or total oxidation indices such as TOTOX [15].

The addition of clove flower extract in this study showed a pattern of decreasing peroxide values that became more pronounced as the extract concentration increased. Concentrations of 0.08%, 0.5%, and 1% showed statistically significant differences compared to the control group, whereas the 0.06% concentration did not show a statistically significant difference. This pattern indicates that the presence of the extract at a certain concentration is necessary to produce a statistically detectable change in the peroxide value. Theoretically, an increase in extract concentration can increase the amount of antioxidant compounds available in the oil system, thereby increasing its capacity to inhibit oxidative reactions. [13]. Cloves are known to contain various phenolic compounds and bioactive components that contribute to their antioxidant activity, with eugenol being one of the key components that has been extensively studied in this plant [16]. Research on the use of clove extract in edible oils has also shown that clove extract can help improve the oxidative stability of oils under accelerated storage conditions [17].

The ability of clove flower extract to reduce the peroxide value can be explained by the activity of phenolic compounds, which play a role in inhibiting the lipid oxidation chain reaction. Phenolic compounds can donate hydrogen atoms or electrons to radical species, thereby helping to stabilize the radicals and inhibit the propagation of oxidative reactions [13] In lipid systems, this mechanism has the potential to reduce the formation of hydroperoxides, which are the initial products of lipid oxidation. The results of this study support the possibility of antioxidant activity in clove flower extract; however, this mechanism cannot yet be directly proven because the study did not identify or quantify the bioactive compounds in the extract. Thus, the relationship between increased extract concentration and a decrease in the peroxide value should be understood as an experimental pattern consistent with the theory of antioxidant activity, rather than as evidence that specific compounds in cloves are the sole cause of these changes. A similar approach was also found in the study by Djikeng et al., which showed that clove extract can have a stabilizing effect on oil during accelerated storage, although its effectiveness is influenced by the type of extract and the condition of the oil used[17].

The research findings also indicate that the extract concentration yielding the greatest chemical effect does not always result in the most desirable organoleptic characteristics. A 1% concentration produced the greatest reduction in the peroxide value but resulted in a more pronounced clove aroma and the presence of sediment, whereas a 0.5% concentration produced a peroxide value below the SNI limit with relatively better organoleptic characteristics. These results indicate that the assessment of treatment effectiveness should not be based solely on a single chemical parameter but should also consider changes in the oil's physical characteristics. Changes in color, aroma, and clarity are characteristics that can influence the perception of oil quality, although these characteristics cannot replace chemical measurements in determining the degree of oxidation. Lipid oxidation products are known to be associated with changes in the sensory quality of oil, including the emergence of undesirable aromas and flavors during the oxidative degradation process. [14], [18]. In the context of this study, the 1% concentration can be considered the treatment with the highest effectiveness in reducing the peroxide value, while the 0.5% concentration shows a better balance between changes in oxidation parameters and organoleptic characteristics.

From a food safety perspective, the results of this study suggest that quality control of used cooking oil should not rely solely on visual indicators such as color and odor. The peroxide value can provide more objective information regarding the primary oxidation process, while additional testing is needed to more comprehensively characterize secondary oxidation products and the degree of oil degradation. [19], [20]. This is important because repeated heating not only alters the peroxide value but can also affect the chemical composition and antioxidant capacity of the oil [11]. Therefore, the potential of clove flower extract demonstrated in this study is more appropriately viewed as an approach to inhibit or suppress the oxidation process, rather than as a method to restore degraded oil to a state equivalent to that of fresh oil. This interpretation is also important from a health perspective because oil that has undergone repeated heating may contain various lipid oxidation products that cannot be fully represented by a single parameter, including the peroxide value [14].

Several limitations should be taken into account when interpreting the results of this study. First, the study used only the peroxide value as the primary parameter for oxidation; therefore, it cannot provide a complete picture of secondary oxidation products and the total degree of oil oxidation. This limitation is significant because hydroperoxides—which form the basis for measuring the peroxide value—can decompose during the oxidation process, meaning that the peroxide value does not always represent all the degradation products that have formed. [21], [22]. Second, the bioactive compounds in the clove flower extract were not quantitatively analyzed; therefore, the specific contributions of eugenol, phenolic compounds, flavonoids, or other components to the antioxidant activity cannot yet be determined. Third, the oil used was sourced from real-world conditions at fried food vendors, so there is potential for variation in oil type, usage history, frying temperature, and the characteristics of the fried food items. These variations are important characteristics of field samples but also limit the generalizability of the results to different oil types and frying conditions. Research on the oils used by fried food vendors also indicates that heating history can affect various physicochemical and antioxidant parameters of the oil [23], [24].

Future research should develop evaluation methods that combine the peroxide value with other oxidation parameters particularly indicators of secondary oxidation products and the total oxidation index so that changes in oil quality can be assessed more comprehensively. [15]. Characterization of the active compounds in the extract particularly phenolic compounds and eugenol—is also necessary to clarify the relationship between the extract's composition and its observed antioxidant activity [25]. Further research could also employ more controlled heating and storage conditions to evaluate the stability of the extract's effects on various types of oil and under different usage conditions. Additionally, quantitative evaluations of safety, stability, and organoleptic acceptability are necessary before the potential of clove flower extract can be further considered for applications in edible oils. Thus, this study provides preliminary evidence that clove flower extract has the potential to reduce primary oxidation indicators in used cooking oil; however, further research is needed to more comprehensively determine its effectiveness, mechanism of action, safety, and conditions of use..

Conclusions

This study shows that clove flower extract (*Syzygium aromaticum*) has the potential to reduce the peroxide value in used cooking oil sourced from fried food vendors. The effectiveness of the treatment showed a tendency to increase with rising extract concentrations, although the lowest concentration did not yield a significant change compared with the control group. In addition to changes in oxidation parameters, the addition of the extract also affected the organoleptic characteristics of the oil, particularly its colour, aroma, clarity and the presence of sediment. These findings suggest that the extract's effectiveness in inhibiting oxidation needs to be considered alongside the oil's physical characteristics; thus, the concentration with the highest chemical effect is not necessarily the most appropriate choice overall.

In practical terms, the research findings provide an initial basis for the development of clove flower extract as a natural source of antioxidants to help control oxidation in used cooking oil. However, these findings cannot yet be used to claim that the addition of the extract can restore oil that has undergone degradation or guarantee the safety of its repeated use. Further research is needed to evaluate more comprehensive oxidation parameters, identify and quantify the bioactive compounds in the extract, and test its stability, safety and organoleptic acceptability under more controlled processing conditions. Such an approach is necessary to determine the most appropriate concentration and conditions of use before the potential of clove flower extract can be further developed for applications in edible oils.

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Informed Consent Statement (optional)

Informed consent was obtained from all subject involved in the study.

Conflicts of Interest (required)

The authors declare no conflict of interest.

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