SYNTHESIS AND ANALYSIS OF THE PROPERTIES OF FATTY ACID AMIDES OF LINSEED OIL

Ilyana Akmalova[1], Vladimir Merkulov[1], Alexander Almazov[1], Elena Sitdikova[1], Nina Gavva[1], Bolat Makhmutov[1], Saule Zhautikova[2]

[1]*Karaganda Industrial University, "Republic" Ave., Bl. 30, Temirtau 101400, Republic of Kazakhstan, ilyanaaa2000@gmail.com (I.A.); smart-61@mail.ru (V.V.); a.almazov@tttu.edu.kz (A.A.); e.sitdikova@tttu.edu.kz (E.S.); n.gavva@tttu.edu.kz (N.G.); b.makhmutov@tttu.edu.kz (B.M.);*
[2]*Karaganda Medical University, "Gogol" St., Bl. 40, Karaganda 100000, Republic of Kazakhstan, zhautikova@qmu.kz (S.Z.)*

Received 18 February 2025
Accepted 11 August 2025
DOI: 10.59957/jctm.v61.i2.2026.4

ABSTRACT

In the recent years, interest in obtaining and studying surfactants synthesized from natural raw materials, has been increased. Flaxseed oil, rich in polyunsaturated fatty acids, is a significant object of study in this field. The synthesis and analysis of the properties of amides derived from linseed oil are important for understanding their potential applications in industry. Previously published studies claimed that the amidation of linseed oil fatty acids is possible only with the use of diethanolamine. However, new research has shown that in addition to diethanolamine, diethylamine can also be successfully used for this process. This discovery opens new prospects for the synthesis of fatty acid amides of linseed oil and expands the possibilities of research in this area.

Keywords: surfactants, foaming properties, fatty acid diethanolamide, fatty acid diethylamide, linseed oil.

INTRODUCTION

In recent years, researchers and technologists have increasingly turned their attention to surfactants derived from renewable sources. Oils such as corn, coconut, palm, and others serve as key raw materials for their synthesis, offering excellent biodegradability, biocompatibility, and reliable performance across a wide range of applications [1].

Fatty acid amides derived from flaxseed oil may be more biodegradable, as they are naturally occurring and can be degraded by microorganisms in nature. Furthermore, using flaxseed oil for the synthesis of diethanolamine may facilitate the disposal of flax processing waste, lowering its negative environmental impact [5, 7, 8].

In the modern world, household chemicals play a vital part in people's daily lives by providing effective cleaning and care for various surfaces. Detergents play a key role in this process, ensuring both cleanliness and health safety [3]. Currently, especially considering the COVID - 19 pandemic, hygiene and disinfection issues are becoming increasingly relevant. Therefore, studies aimed at developing effective antimicrobial components for detergents may be of practical value to society.

Fatty acid amide is one of the key components that has both bactericidal and foaming properties. This unique ingredient is an ideal combination of functional characteristics that not only help to eliminate dirt but also ensure safety and hygiene. Fatty acid amide is a surface - active substance that has disinfecting, wetting, foaming, and anti-corrosion properties [2]. It is a substance with strong bactericidal activity, capable of destroying microorganisms and hindering their reproduction. Its use in detergents not only ensures effective surface cleaning but also provides an additional level of protection against potential contamination.

Fatty acid diethylamides and diethanolamides can be used as foaming agents in the flotation process due

to their surface-active properties. They promote the formation of stable foam that binds to minerals and allows them to rise to the surface of the flotation cell for subsequent collection [4, 6].

As a result of their chemical properties, these substances have important industrial applications as surface-active substances and foaming [1].

EXPERIMENTAL

0.100 L of flaxseed oil is placed in a three-necked flask with a stirrer followed by 0.350 L of diethanolamine. Then 0.2 g of a catalyst, which in this case is potassium hydroxide, is added. The catalyst is usually added gradually to avoid an intense reaction. The reaction mixture is stirred and heated to a certain temperature (usually in the range of 150 - 200°C) and maintained at this temperature for 3 - 4 h [8].

Once the reaction is complete, the product is cooled, and water is added to separate the diethanolamides from the reaction mixture.

The process of chemical interaction between diethanolamine and triglyceride proceeds as follows:

0.100 L of flaxseed oil is placed in a three-necked flask with a stirrer and 0.06 L of diethylamine is added. Then the catalyst, in this case potassium hydroxide, is added. To avoid an intense reaction, the catalyst is usually added gradually.

The reaction mixture is stirred and heated to a certain temperature (usually in the range of 150 - 200°C) and maintained at this temperature for 3 - 4 h.

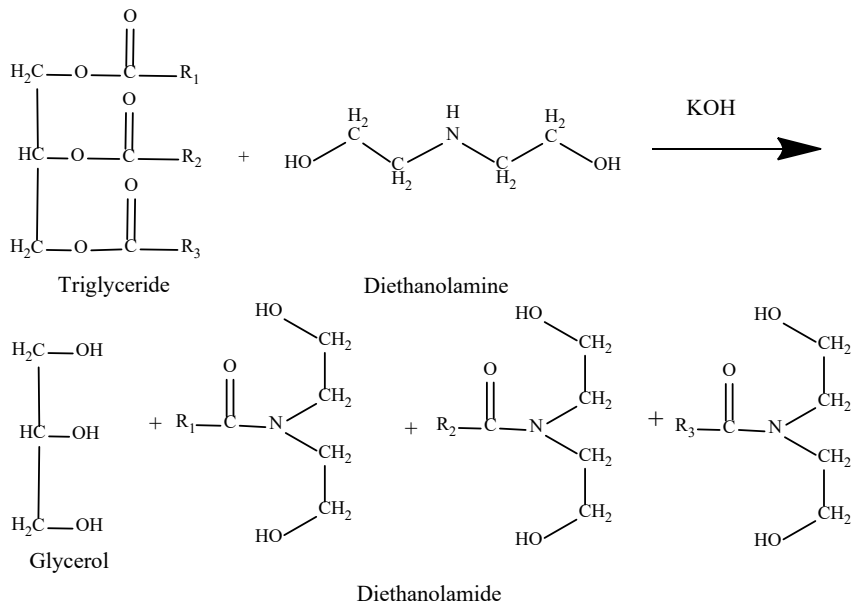
The process of chemical interaction between diethylamine and triglyceride proceeds as follows:

Once the reaction is complete, the product is cooled, and water is added to separate the diethylamides from the reaction mixture [10 - 11].

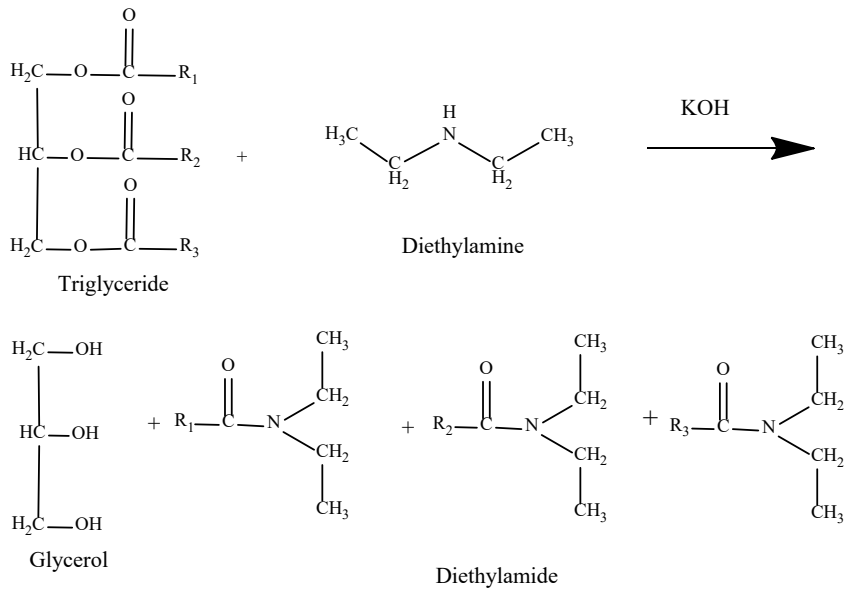
FT - IR spectroscopy

The structure of the obtained diethanolamide is confirmed by IR spectroscopy data (Fig. 1a). The spectrum confirms the presence of amide groups in the substance: there are characteristic bands of C=O (amide I), N–H (amide II), as well as a wide band of O–H/N–H in the region of 3300 - 3400 cm^{-1}. Bands in the region of 2850 - 2950 cm^{-1} indicate the presence of methylene chains, typical of fatty acid residues.

The structure of the obtained diethanolamide is confirmed by IR spectroscopy data (Fig. 1b). IR spectrum (v, cm^{-1}): 1471.69 (amide III); 1720.48 (amide II); 2848.86; 2914.44 (CH_2, CH, CH_3); 3300 (N - H) (Fig. 1b). Study and comparison of the physicochemical properties of flaxseed oil fatty acid amides .



Scheme 1. Scheme of the reaction for obtaining flaxseed oil fatty acid diethanolamides.



Scheme 2. Scheme of the reaction for obtaining flaxseed oil fatty acid diethylamides.

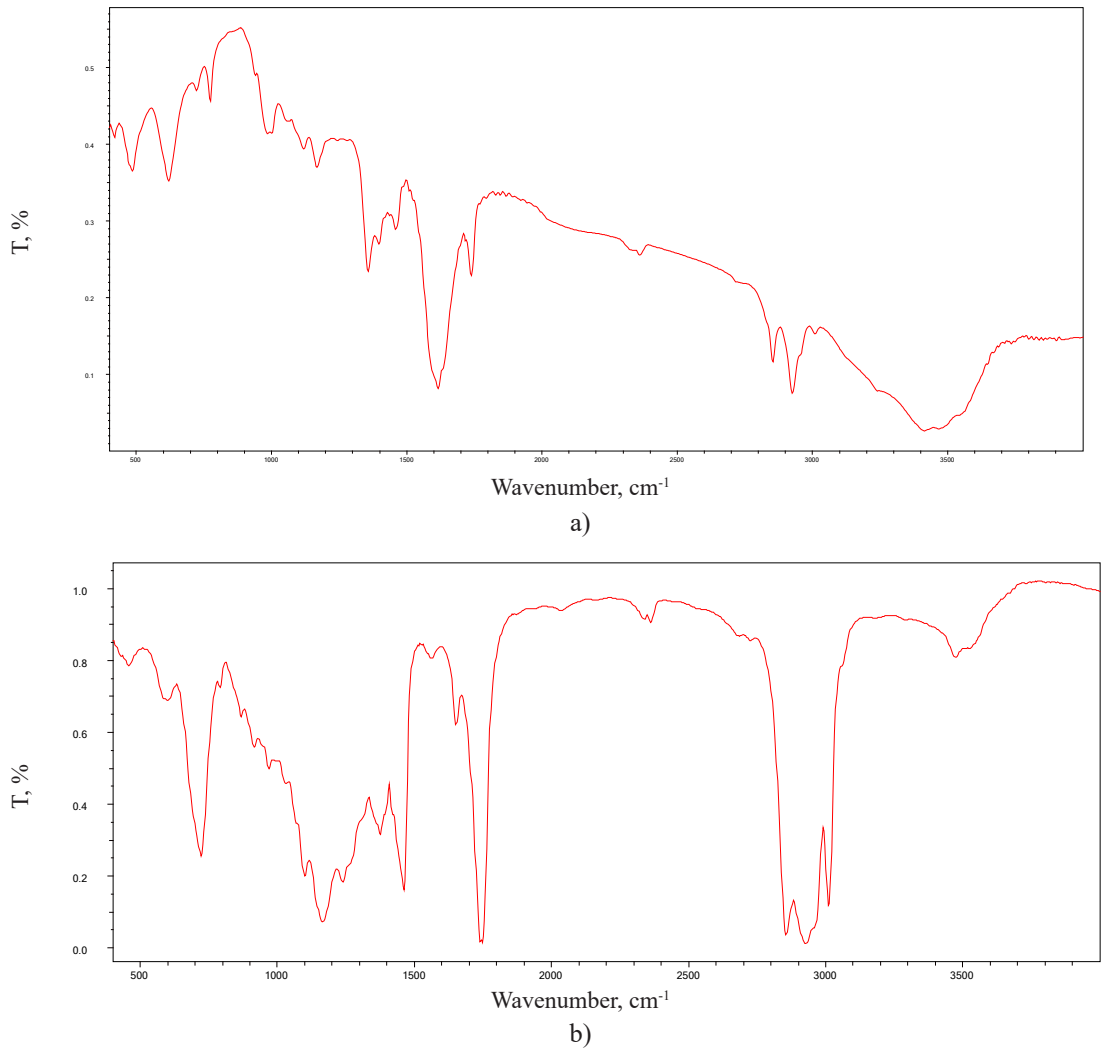


Fig. 1. IR spectrum of (a) - flaxseed oil fatty acid diethanolamide (b) - flaxseed oil fatty acid diethylamide.

Study and comparison of physicochemical properties of flaxseed oil fatty acid amides

Understanding the structure and properties of flaxseed oil fatty acid amides is useful in researching their functional properties. These compounds are widely used in industry, including in the production of detergents and cosmetics. The study of their physicochemical properties allows optimizing their use and development of new products based on flaxseed oil. That is why the obtained amides were analysed for foaming, bactericidal, anti-corrosion, and physical properties, and the pH value was also determined [2].

The resulting fatty acid amides are readily soluble in a range of solvents, including isopropyl alcohol. When fatty acid amides are dissolved in isopropyl alcohol, a transparent solution is formed that can be easily mixed with other components to produce various products. This property makes isopropyl alcohol a popular choice to produce detergents, shampoos, and other products that require good solubility of fatty acid amides. Therefore, solutions of surface - active substances with a concentration of 30 % and 50 % were prepared to analyse the physical characteristics of the samples.

Table 1 illustrates the physical characteristics of the obtained surface-active substances from fatty acids of animal fat.

The capacity of surface-active substances to foam is the most important measure of their effectiveness. Foaming ability is the volume of foam formed under certain conditions (temperature, concentration of surface-active substance, foaming method) from a certain volume of solution. The volume of foam formation and the duration of its existence can be used to quantify this feature [1]. The formation of stable foam indicates good quality of the surface-active substance; therefore, this property is also tested in the conditions of industrial synthesis of these compounds.

The foaming ability of the surface-active substance was determined in accordance with GOST 22567.1 - 77 by measuring the height of the foam column obtained by shaking several drops of the studied surface-active substance and a certain volume of distilled water in a graduated cylinder. (Fig. 2)

The study of the antimicrobial properties of flaxseed oil fatty acid amides allows us to assess its ability to destroy or inactivate microorganisms such as fungi. This is important for determining its potential as an antimicrobial agent that can be used to combat infectious diseases or as a preservative in the food and cosmetics industries. The determination of antimicrobial properties was carried out using the disk diffusion method. The disk diffusion method (often called the Kirby - Bauer method) is one of the standard methods for determining the antimicrobial activity of compounds against bacteria or fungi. This method is widely used in microbiological and clinical diagnostic laboratories [2].

The method for analysing the antimicrobial activity of fatty acid diethanolamide using the disk diffusion method was as follows:

For further study of their antimicrobial activity, solutions of fatty acid diethanolamide and diethylamide of various concentrations were prepared in advance and culture of Mucorales fungal microorganisms was grown on an agarin nutrient medium [2].

Then, filter paper disks impregnated with 0.01 mL of the studied surface-active substance sample of various

Table 1. Physical characteristics of surfactants.

The name of characteristics	Surface-active substance	
	Diethanolamide	Diethylamide
Appearance and consistency	Oily, viscous liquids with a pleasant odor	
Colour	Light brown	Dark brown
Smell	Nice smell	

Fig. 2. Determination of foaming ability of flaxseed oil fatty acid diethanolamide and diethylamide samples.

concentrations were placed on the surface inoculated with microorganisms. Solvent-impregnated disks were used as a control. One disk was placed on one dish and incubated for 5 days at 20 - 37°C.

After incubation, the microorganism growth inhibition zones around the disks with fatty acid diethanolamide were assessed using a microscope. The wider the inhibition zone, the higher the antimicrobial activity of the substance.

During disposal, used detergent solutions containing various surface- active substances come into contact with metal sewer pipes, as well as during washing of metal utensils made of various iron and aluminum alloys. Using fatty acid amides as surface - active substances will help protect pipes from corrosion and even suppress it.

As part of this study, samples were made in the form of iron plates. Cleaned plates were immersed in glasses with a 0.1 % surfactant solution and left for some time. Every three days, rust formation on the samples was checked. This study is shown in Fig. 3.

A rust test in tap water was also used as a control sample.

Fig. 3. Determination of the corrosion resistance of samples of diethanolamide and diethylamide of linseed oil fatty acids.

RESULTS AND DISCUSSION

At the conclusion of the synthesis, fatty acid diethanolamides and diethylamides were obtained, as evidenced by changes in the reaction mixture, namely: after 1 h, the two phases begin to mix, resulting in a reaction and the liquid in the flask becoming homogeneous, while an external change in the colour of the reagents in the breaker is observed.

It was discovered that amidation products of these acids can be obtained using raw animal materials that contain fatty acid triglycerides in their composition. In the framework of this study, the successful use of diethylamine for this process was discovered. This discovery opens new prospects for the synthesis of flaxseed oil fatty acid amides and expands the possibilities of studies in this area.

The results acquired for the primary quality indicators are consistent with the requirements of various manufacturers' technical specifications, indicating that the items obtained are of high quality.

Foaming determination results:

Test sample 1: flaxseed oil fatty acid diethanolamide, foaming capacity is 0.030 L;

Test sample 2: flaxseed oil fatty acid diethylamide, foaming capacity is 0.035 L;

It is worth mentioning that diethanolamide foam is more stable; yet, with active exposure, the foaming property of diethylamide is more pronounced. During the flotation process, the foaming agent must form a stable foam. This is because foam is a key element of the flotation process, facilitating the separation of valuable minerals from waste. The environmentally friendly foam ensures the effective separation of minerals by holding valuable minerals on the surface and preventing them from settling in the process.

Corrosion stability analysis showed that samples immersed in amide solutions exhibited no rust formation after 3 days, indicating that these compounds may function as corrosion inhibitors.

The results of the antimicrobial activity analysis of fatty acid diethanolamide using the disk diffusion method are provided in Table 2.

The analysis results show that when the concentration of fatty acid amides increases, so does the microorganism growth inhibition zone. This indicates that these compounds have antimicrobial activity and may be effective against bacteria or fungi.

Table 2. Results of determination of antimicrobial activity.

Concentration	Microbial growth inhibition zone of fatty acid diethanolamide, mm	Microbial growth inhibition zone of fatty acid diethylamide, mm
0.1 %	8	10
0.5 %	16	15
1.0 %	19	20
2.0 %	25	25

CONCLUSIONS

This study synthesized and analyzed the properties of flaxseed oil fatty acid amides.

The synthesis of fatty acid amides was carried out by the reaction between flaxseed oil fatty acids and amines. Several amines, including diethylamine and diethanolamine, were utilized for this purpose. The reaction was performed under certain conditions, including the optimal temperature and reaction time.

The results show that amides can be successfully synthesized using flaxseed oil fatty acids. The compounds obtained were analysed and shown to have various valuable properties, including high foam stability, antimicrobial and anticorrosive properties, and the potential for application as surface-active substances.

Thus, the study's findings make a significant contribution to the understanding of the chemical properties of flaxseed oil fatty acid amides and can serve as a foundation for future research in this field.

REFERENCES

1. I. Akmalova, V. Merkulov, A. Almazov, E. Sitdikova, Study of the properties of a new detergent based on cationic surfactants, in: Proc. XI Int. Sci. Pract. Conf. "Science and Education in the Modern World: Challenges of the XXI Century", Astana, Kazakhstan, 2022, 25-30.
2. I.M. Akmalova, V.V. Merkulov, Method of obtaining surfactants based on various fatty raw materials, News Natl. Acad. Sci. Repub. Kazakhstan, Chem. Technol. Ser., 2, 2023, 5-14.
3. A.E. Karaulov, V.G. Rybin, D.V. Kuklev, Synthesis of fatty-acid ethanolamides from Linum catharticum oils and Cololabis saira fats, Chem. Nat. Compd., 40, 2004, 222-226.
4. A. Adewuyi, Synthesis and surface-active property of diethanolamide and epoxidised diethanolamide surfactant from the seed oil of Baphia nitida, Arab. J. Chem., 12, 7, 2016, 1545-1551. doi:10.1016/j.arabjc.2014.10.021
5. A. Toshkhuzhaev, A.. Tillaev, O. Vafaev, A. Jalilov, Synthesis and research of surfactants based on fatty acids of cottonseed oil and diethanolamine, Universe: Tech. Sci., 7-3, 2022.
6. C.J. Lee, Synthesis of palm oil-based diethanolamides, J. Am. Oil Chem. Soc., 2007.
7. G. Gervajio, Fatty acids and derivatives from coconut oil, in: Kirk-Othmer Encyclopedia of Chemical Technology, 2005.
8. H. Kolancılar, Preparation of laurel oil alkanolamide from laurel oil, J. Am. Oil Chem. Soc., 81, 2004, 597-598.
9. A. Bilyk, R. Bistline, G. Piazza, S. Feairheller, M. Haas, A novel technique for the preparation of secondary fatty amides, J. Am. Oil Chem. Soc., 69, 5, 1992, 488-491.
10. K.R. Lange, in: L.P. Zaichenko , Surfactants: Synthesis, Properties, Analysis, Application, Moscow, Chemistry, 2004.
11. A.E. Kretov, A.P. Moiseenko, Method of obtaining amides, Bull. Inventions, 18, 1981.