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SAFETY**

**BIOLOGICAL, CHEMICAL, AND
ENVIRONMENTAL THREATS
DURING WAR**

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FIRE HAZARDS AND TOXICOLOGICAL PROPERTIES OF VEGETABLE OILS

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This paper examines the processes of thermal degradation of vegetable oils during heating and the associated toxicological and fire hazard risks. The formation of harmful compounds – such as acrolein, polycyclic aromatic hydrocarbons (PAHs), and trans fats – is described, as well as their effects on the human body. Fire suppression methods for Class F fires are analyzed, including the use of fine water sprays and inert gases. Relevant experimental data are provided, confirming the effectiveness of modern fire extinguishing systems and the toxicity of products formed during repeated heating of oils.

Vegetable oils are widely used in the food, cosmetic, and chemical industries. Despite their organic origin, under certain conditions, they can pose significant risks to human health and the environment. Particular attention is paid to the fire hazards and toxicity of the products generated during the thermal decomposition of oils. According to [1], fires caused by the ignition of vegetable oils or animal fats are classified as Class F fires and exhibit specific combustion characteristics.

Fires resulting from the ignition of vegetable oils or animal fats used for frying are classified as Class F fires, as defined in [1]. This class is distinguished due to the specific conditions of ignition and extinguishment of such substances, namely:

- the combustion temperature typically exceeds 300 °C;
- the flammable liquid possesses high viscosity and heat capacity, complicating the cooling of combustion products;

– during extinguishment, the contact of water with hot oil causes instantaneous vaporization, leading to the expulsion of burning liquid – an effect known as explosive splattering [2].

Extinguishing with water is strictly prohibited! This rule is critical for personnel safety, as water not only fails to extinguish the fire but significantly exacerbates it. Modern methods for extinguishing vegetable oil fires include:

- water Mist Fire Suppression;
- water Mist combined with Inert Gases.

Water mist is a fire suppression system that produces fine droplets with diameters less than 100 micrometers. This system offers several advantages over conventional water jets:

- rapid temperature reduction – due to the large surface area of the fine mist, heat is efficiently removed from the ignition zone;
- fuel–oxygen isolation – the steam generated upon contact with a hot surface forms a barrier that partially blocks oxygen access;
- reduction of smoke and toxic by-products – fine droplets capture aerosols, improving evacuation conditions [3].

The authors of [3, 4] have demonstrated that water mist systems can reduce the surface temperature of oil from 360 °C to below its flash point (< 300 °C) within 30–40 seconds. Combined systems include: water mist + inert gases (nitrogen, CO₂, argon). An innovative approach involves combining water mist with the injection of inert gases. Such a system operates in three key ways:

- temperature reduction (cooling);
- reduction of oxygen concentration (below 15% – the level at which combustion becomes impossible);
- flame suppression by creating an oxygen-depleted atmosphere around the fire source.

In [2], it was shown that the use of nitrogen in combination with water mist can reduce flame intensity by 80–90% within the first few minutes of extinguishing, without the risk of re-ignition (see Table).

Table
Advantages of Modern Fire Suppression Methods

Suppression Method	Advantages	Disadvantages
Water Mist	Efficient cooling, low water consumption, safe for electrical equipment	Requires specialized equipment
Inert Gases	Leave no residue, inhibit combustion at the molecular level	May pose health risks in poorly ventilated spaces
Combined Systems	Highest efficiency, suitable for industrial kitchens and chemical labs	High installation cost

Upon heating vegetable oils, particularly with repeated use in cooking, thermal and oxidative degradation of triglycerides occurs. This leads to the formation of a number of hazardous compounds, including acrolein. Acrolein is produced by the dehydration of glycerol, a by-product of triglyceride breakdown. It is a volatile compound with a pungent odor that irritates the mucous membranes of the respiratory tract. Acrolein has been shown to have genotoxic and carcinogenic activity [5].

Polycyclic aromatic hydrocarbons (PAHs) form during overheating of oils (above 350 °C), especially in the presence of food residues or smoke. The most notable representatives – benzo[a]pyrene and chrysene – are classified as Group 1 carcinogens by the IARC [6].

Trans fats – trans-isomers of unsaturated fatty acids – are generated under high-temperature conditions, particularly in industrial processing. They negatively affect blood lipid profiles by increasing LDL (low-density lipoproteins) and decreasing HDL (high-density lipoproteins), thereby elevating the risk of cardiovascular diseases.

Laboratory studies on animals and epidemiological observations point to the adverse effects of long-term consumption of foods prepared using repeatedly heated vegetable oils, including:

- hepatotoxicity – lipid accumulation in the liver, hepatocellular inflammation;
- hypertension – repeated heating increases oxidized lipid levels that impair vascular reactivity;
- inflammatory responses – elevated levels of interleukin-6 (IL-6) and C-reactive protein;
- cell membrane damage caused by free radicals and lipid peroxidation (LPO).

In the study [7], laboratory rats were fed a diet containing repeatedly used oils. The results showed a significant increase in malondialdehyde (MDA) levels – an established biomarker of oxidative stress – as well as a decrease in antioxidant enzyme activity (catalase and superoxide dismutase). Thus, excessive consumption of repeatedly heated oils may have serious health consequences and requires further investigation and regulatory oversight.

The conducted analysis demonstrates that, despite their natural origin, vegetable oils, under conditions of prolonged or repeated heating, become a source of numerous toxic and carcinogenic compounds, such as acrolein, polycyclic aromatic hydrocarbons (PAHs), and trans fats. The formation of these substances not only deteriorates the organoleptic properties of food products but also poses a serious health hazard, causing hepatotoxicity, impaired vascular regulation, oxidative stress, and inflammatory responses. The presence of free radicals and lipid peroxidation products is closely associated with the development of chronic diseases, including atherosclerosis and cancer.

Special attention in this study is given to the fire hazards associated with the ignition of overheated vegetable oils, classified as Class F fires. It has been established that traditional extinguishing methods (particularly the use of water) are not only ineffective but also dangerous due to the risk of explosive splashing. In this context, modern fire suppression systems based on water mist and inert gases demonstrate high effectiveness, owing to their ability to rapidly lower temperature and block oxygen access.

Therefore, in order to mitigate both toxicological and fire-related risks associated with the use of vegetable oils, it is advisable to implement advanced thermal processing control technologies, ensure the regular replacement of oils, utilize specialized fire suppression systems, and develop appropriate national sanitary and fire safety regulations.

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