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ENTREPRENEURIAL OPPORTUNITIES AND CHALLENGES IN THE UKRAINIAN BIOFUEL MARKET: HARNESSING ANIMAL FATS FOR SUSTAINABLE ENERGY

This article explores the economic potential of Ukrainian private enterprises in the fields of entrepreneurship and business, utilizing animal fats as feedstock for first- and second-generation biofuels. As Ukraine strives to enhance its energy security and promote sustainability, this byproduct presents a promising opportunity for innovative renewable energy solutions. The study assesses market availability, economic viability, and environmental benefits, offering insights for enterprises entering this sector.

Keywords: *entrepreneurship, sustainability, startup, business, market, renewable energy, second-generation biofuels, Ukraine.*

Problem Statement

Ukraine's growing need for sustainable energy sources and the government's commitment to biofuel integration by 2025 highlight the importance of developing innovative energy solutions [1][2].

The Ukrainian biofuels market is facing significant challenges due to the oversaturation of conventional bioethanol production facilities. These facilities are in intense competition for limited feedstocks such as corn, sugar beet molasses, and other agricultural products, which are also in high demand for food, feed, and export purposes. This competition drives up feedstock prices, making bioethanol production increasingly cost-prohibitive and economically unsustainable. Consequently, the profitability margins for bioethanol plants are being eroded, threatening the overall sustainability of the industry.

To address these challenges, it is imperative to diversify the spectrum of biofuels produced and to advocate for the use of non-food feedstock alternatives. Recent legislative mandates requiring the blending of both gasoline and diesel fuels starting with June 2025 accentuate the urgency of this issue. Furthermore, there is a discernible shift away from traditional biodiesel feedstocks such as rapeseed and soybeans, driven by the capping of conventional food feedstocks as stipulated in the Renewable Energy Directive III (RED III). [3]

This regulation aims to limit the use of food-based feedstocks in biofuel production to mitigate food security concerns and promote the use of more sustainable and non-food alternatives. By concentrating on alternative feedstocks, such as agricultural residues and waste for the production of second-generation biofuels, market pressures can be mitigated. This strategic focus ensures a consistent supply of cost-effective raw materials for biofuel production, thereby enhancing the sustainability and growth potential of the biofuels industry in Ukraine.

Biofuel businesses in Ukraine have a unique opportunity to leverage animal fats as a feedstock for second-generation biofuels, addressing both environmental concerns and the country's energy needs. The primary challenge for Ukrainian bioenergy start-ups is identifying sustainable and economically viable feedstocks. Animal fats offer a solution for potential market pioneers in production of biodiesel and renewable diesel, but their effective use requires a detailed analysis of the potential capacity, economic challenges and environmental impacts.

The ongoing Russia-Ukraine War further exacerbates the challenges faced by the Ukrainian business, particularly biofuels market [4]. The war has disrupted supply chains, damaged infrastructure, and created labor shortages, particularly in livestock farming, which could directly impacts the availability of animal fats. These disruptions have led to a reduction in livestock numbers and have affected the production capabilities of the meat processing industry. Additionally, the conflict has hindered export channels for animal fats, leading to potential shortages in international markets and increased prices. Despite these challenges, the conflict presents an opportunity for start-ups to redirect animal fats toward domestic biofuel production. By focusing on second-generation feedstock, start-ups can contribute to reducing waste, creating a sustainable energy source, and supporting Ukraine's energy independence amidst the ongoing turmoil.

Analysis of recent research and publications

The insights from **Geletukha et al. (2023)** provide a critical understanding of the current state and challenges of the Ukrainian bioethanol market. They underscore the importance of adopting advanced biofuel technologies and diversifying feedstocks to maintain the economic and environmental sustainability of biofuel production in Ukraine.[5] Recent research by **Hönig et al. (2016)** [6] evaluated the economic viability of biodiesel production from waste animal fats. They found that the production cost is significantly lower compared to vegetable oils, mainly due to the lower price of animal fats. Additionally, they noted that the market for animal fat-based biodiesel is expanding, driven by increasing regulatory support and market demand for sustainable fuels. A comprehensive review by **Feddern et al. (2011)** [7] highlighted the economic benefits of using waste

animal fats, noting that the cost of these fats is generally lower than that of vegetable oils. Their study emphasized the importance of pre-treatment processes to improve the quality of the raw material, which in turn affects the overall cost-efficiency of the biodiesel production process **Baladincz and Hancsók (2015)** [8] conducted an extensive study on the utilization of waste animal fats for biofuel production. They highlighted that waste animal fats, including brown grease and lard, can be effectively converted into biofuels through hydrogenation and isomerization processes. The study emphasized the low cost and zero indirect land use change (iLUC) value of these feedstocks, making them economically viable alternatives to conventional raw materials. These studies consistently highlight the economic advantages of using animal fats for biodiesel production. The lower purchase price of animal fats and technological advancements support their economic viability and market potential. This research provides crucial insights for Ukrainian start-ups aiming to enter the biofuel market, offering a competitive and sustainable alternative to conventional feedstocks.

Forming the purpose of the article

The article aims to highlight the entrepreneurial potential of leveraging animal fats for biofuel production amidst the disruptions caused by the Ukraine conflict. It explores the challenges and opportunities for renewable energy entrepreneurs, emphasizing the benefits of utilizing animal fats as a sustainable energy source and fostering innovation in the industry.

Presentation of the main material

Entrepreneurial aspect of animal fats as a potential feedstock for biodiesel plants and renewable diesel plants

Biodiesel is produced via transesterification, a catalytic process, while green diesel, also known as hydrotreated vegetable oil (HVO), is made through catalytic hydrotreating of oil. Both biofuels offer distinct advantages and challenges when compared to conventional diesel.

Biodiesel and HVO are evaluated based on various properties such as cloud point, pour point, flashpoint, fire point, cetane number, acid value, oxidative stability, and iodine value. Biodiesel is composed of alkyl esters of fatty acids with oxygen and carbon double bonds, making it susceptible to hydrolysis and oxidation. Conversely, HVO is made up of paraffinic hydrocarbons without oxygen and double bonds, resembling fossil diesel more closely and thus can be blended with it without significant issues.HVO generally has a higher cetane number and lower density than biodiesel, while biodiesel exhibits higher viscosity and density. Biodiesel burns cleaner, reducing engine smoke and emissions of CO2 and sulfur, though it increases NOx emissions. Additionally, biodiesel offers better lubricity, reduces engine wear, and is biodegradable in water, unlike fossil diesel. Despite biodiesel's lower caloric value and higher consumption compared to diesel, its cleaner burn and environmental benefits make it a valuable alternative fuel. HVO's performance is hindered at low temperatures due to high paraffin content compared with fossil diesel, but it still represents a promising diesel substitute when additives are used to improve its properties.

The composition of biodiesel production costs includes several key components. Feedstock costs are typically the largest, constituting 70-88% of total production costs, influenced by the prices of vegetable oils, animal fats, or waste oils [9,10]. Processing costs encompass energy, labor, maintenance, and operational expenses, with smaller operations facing higher per-unit costs [10,11]. Biodiesel production plants with capacities of 60,000 tonnes per year (tpy) or more can significantly reduce production costs. Beyond this threshold, further capacity increases continue to improve process viability and reduce cost. While the total capital investment for larger plants is higher, the cost per unit of biodiesel produced decreases, making mass production more economical. This trend is evident in studies that show the capital investment required increases proportionally with plant size but at a decreasing rate per unit of output. Economic evaluations indicate that larger plant capacities result in higher NPV, making investments in larger biodiesel plants more attractive. For instance, a catalytic hydrogenation process showed an increase in NPV from $7 million to $53.1 million when plant capacity was increased from 100,000 tpy to 200,000 tpy [11]. Capital costs involve the initial investment in equipment and infrastructure, amortized over time. Glycerol revenue, from selling the byproduct, can offset some costs, though market variability affects this income [8][9]. Lastly, miscellaneous costs cover environmental compliance, quality control, insurance, and administrative expenses [12]. The use of animal fats as feedstock in conventional catalytic biodiesel production is challenging due to their high free fatty acid (FFA) and water content compared to vegetable oils. These impurities increase processing costs because they require additional pre-treatment stages to avoid reduced yields caused by the formation of soaps, which complicate the separation of biodiesel from glycerol. To address this, alternative methods like non-catalytic synthesis in supercritical alcohol have been suggested. Despite these challenges, animal fats are a cost-effective alternative to refined vegetable oils. For instance, chicken fat with a low FFA content (4 wt%) can produce biodiesel without generating glycerol by using a minimal excess of methanol [13]. A research was conducted among leading technology suppliers in the European Union and the United States, revealing that the production of biodiesel, when constructing plants with an output of more than 50,000 tons per year, has a Total Installed Cost (TIC) ranging from $530 to $640 per ton

per year (tpy). The technology that could handle up to 20% of FFA without substantial decrease in conversion rate starts at 580$/tpy.

Sustainability and potential of animal fats in biofuel production

Using animal fats for biodiesel should be balanced with food security considerations, especially in regions where fat consumption is low, and undernourishment is high. Ensuring that the production of biofuels does not compete with food resources is critical for sustainable development. Animal fats used in biodiesel production could be considered a sustainable choice when they are by-products of the meat industry, reducing waste and making use of all parts of the animal. This aligns with the idea of using resources more efficiently and minimizing waste. Using animal fats for biodiesel has distinct environmental benefits compared to vegetable oils like rapeseed and soybean oils. A Life Cycle Assessment (LCA) study highlighted that biodiesel from animal fats, such as beef tallow and poultry fat, has a lower Global Warming Potential (GWP) compared to biodiesel from rapeseed and soybean oils. For example, the GWP of biodiesel from beef tallow is 23.32 kg CO2 eq per GJ, while soybean biodiesel has a GWP of 26.18 kg CO2 eq per GJ, and rapeseed biodiesel stands significantly higher at 63.23 kg CO2 eq per GJ [14]. Understanding the difference between edible and waste animal fats aids in proper waste management and environmental sustainability. Waste animal fats, often by-products of the meat processing industry, can be repurposed for non-food applications such as biodiesel production, soap making, and animal feed. This not only reduces waste but also contributes to a circular economy by turning by-products into valuable resources. Differentiating between these types of fats helps prevent food fraud and ensures regulatory compliance. Regulatory bodies impose different handling and usage guidelines for edible and waste fats, and proper identification helps businesses comply with these regulations, avoiding legal issues and maintaining consumer trust. Discarded Animal Fats (DAF) are fats that have been rejected or deemed unsuitable for their intended primary use, often due to quality issues or contamination. Discarded animal fats typically come from food processing and slaughterhouses where the fats do not meet the necessary standards for food or other high-value applications. According to the Food and Agriculture Organization (FAO), discarded animal fats can arise from various stages of meat processing where they are considered by-products or waste materials that require proper disposal or repurposing to avoid environmental harm [15]. Waste Animal Fats are fats derived from the by-products of meat processing industries, including tanneries and slaughterhouses. Waste animal fats are often classified based on their origin, such as tallow from cattle, lard from pigs, and poultry fat. These fats are typically not suitable for human consumption due to their quality or contamination levels but are considered valuable feedstocks for industrial applications such as biofuel production. According to the Renewable Energy Directive II (RED II) of the European Union, waste animal fats are included in Annex IX, which lists feedstocks for advanced biofuels, emphasizing their importance in sustainable energy production. These fats include tallow from cattle, lard from pigs, and poultry fat. While these fats are generally not suitable for human consumption due to their quality or contamination, they are highly valued for industrial uses like lubricants, biodiesel, plasticizers in biodegradable films, metal cutting fluids, antimicrobial wound dressings, paint binders, and cosmetic ingredients. [16,17].

According to REGULATION (EC) No 1069/2009, animal fats are classified based on their risk to human and animal health:

Category 1: High-risk materials, including animals with diseases like TSE. These must be incinerated.

Category 2: Medium-risk materials, such as manure and animals that die from causes other than slaughter. These can be used for biogas production or composting.

Category 3: Low-risk materials, which include parts of animals that are fit for human consumption but are not intended for it. These can be used for pet food, biodiesel, and other non-food applications.

This classification system helps ensure that animal by-products are managed safely while allowing the beneficial use of lower-risk materials in various industries [18]. Waste animal fats from Category 3 are particularly useful for biofuel production, aligning with the EU's goals for sustainable energy and waste reduction. However, certification schemes and certification bodies have been established to ensure that animal fats intended for human consumption are not diverted for energy purposes. These regulatory mechanisms are critical in maintaining the integrity of the food supply chain and preventing the misuse of edible animal fats. Certification processes, such as those outlined by the International Sustainability and Carbon Certification (ISCC) and other similar organizations, provide rigorous standards and traceability protocols. These standards ensure that only non-edible animal fats, classified under appropriate risk categories, are utilized for biofuel production and other industrial applications, thereby safeguarding public health and food resources.

In conclusion, Category 3 animal fats, while not strictly classified as second-generation feedstocks, do not compete with the food industry or feed crops, making them valuable for biofuel production. On the other hand, Category 1 and 2 animal fats qualify as second-generation feedstock but are challenging to source and process due the lack of rendering plants that process carcasses in Ukraine. These facilities that process animal

by-products and carcasses into valuable materials such as bone meal and fats and are crucial for handling the disposal of animal carcasses, including those that may be infected with diseases like African swine fever (ASF). High-Temperature Rendering is a widely used technology where animal tissues are cooked at temperatures exceeding 130°C under high pressure. This process is highly effective in killing pathogens and separating fat from protein and moisture, resulting in valuable products like tallow and bone meal. This method not only ensures the safe disposal of animal by-products but also provides additional sources of animal fats for various markets, including Ukraine. Alkaline Hydrolysis, on the other hand, employs a solution of water and potassium hydroxide (or sodium hydroxide) at high temperatures and pressures to decompose animal tissues into a sterile, nutrient-rich liquid and a small amount of solid residue. This technology is particularly suited for high-risk biological materials as it guarantees the complete destruction of pathogens. The resulting liquid, rich in nutrients, can be utilized as a fertilizer, thus promoting a sustainable cycle of waste management. By adopting such technologies, Ukraine can enhance its capacity to manage animal by-products sustainably and potentially increase the supply of waste animal fats for the market.

Study of the Ukrainian animal fat market

The animal fats industry in Ukraine is significantly affected by the Russia-Ukraine war. The war has led to a reduction in livestock farming due to the destruction of facilities and the displacement of farmers. This reduction in livestock numbers directly impacts the availability of animal fats.

The Ukrainian poultry, beef, and pork industries have faced significant challenges due to the ongoing conflict, logistical disruptions, and market dynamics. The poultry sector, despite showing resilience, is recovering gradually with production levels not expected to return to pre-war levels. Increased production costs, energy shortages, and logistical problems persist, though low feed costs remain a competitive advantage. Exports, primarily to the EU, continue to be significant, driven by trade liberalization and strong domestic demand for affordable protein [19]. The Ukrainian dairy and meat industries have been heavily impacted by the war. Around 43% of industrial cattle and 42% of milk production are affected, with significant losses in Kharkiv, Sumy, and Chernihiv regions. Relocation efforts have increased livestock numbers in safer regions. The meat industry faces supply chain disruptions, infrastructure damage, and altered market dynamics due to the conflict, affecting both production and distribution [20,21].

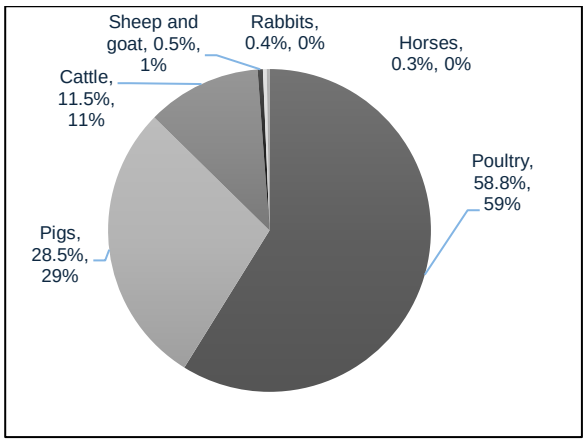

Figure 1. Animal farming structure according to State Statistics Service of Ukraine [22]

The waste animal fats market in Ukraine is primarily driven by the poultry and pig farming industries, given their significant share in the overall animal farming structure. These two sectors produce the bulk of waste fats, with cattle farming also contributing to a lesser extent. As a result, efforts to optimize the collection and processing of waste fats from these industries can substantially impact the availability and efficiency of biofuel production and other applications in Ukraine.

A comprehensive survey of major meat producers and rendering enterprises, along with an analysis of available export statistics for fats from Ukraine, has revealed key data on the potential feedstock of waste fats. The study indicates that substantial quantities of animal fats:

Table 1

A comprehensive survey of major meat producers and rendering enterprises

Type of waste oil	tons per month	tons per year
Poultry fats cat. 3 & cat. 2	4200	50400
Beef fats cat. 3 & cat. 2	300	3600
Pork fats cat. 3 & cat. 2	1200	14400
Beef/pork mixed fat cat. 3 & cat. 2	800	9600
WCO	400	4800
Total	6900	82800

Though these quantities are not large enough to meet the capacity of large-scale biodiesel/renewable diesel plant with over 100,000 tpy capacity, they could provide the significant additional to more traditional oil feedstock for the biodiesel and green diesel plants in Ukraine. Ukrainian biofuel producers can gain competitive advantages through lower raw material costs by saving on logistics and benefiting from lower prices from local suppliers. Proximity to agricultural areas reduces transportation costs and delivery times, while local farmers can offer raw materials at more competitive

prices compared to EU market. Additionally, utilizing local energy sources like agricultural waste for biogas production can further reduce production costs and promote eco-friendly processes.

Households are the most vulnerable to the challenges of war, with the number of animals decreasing every month. In contrast, agricultural enterprises have shown greater resilience to wartime challenges. This resilience is partly due to the ability to relocate livestock farms to safer areas, as evidenced by the increase in livestock numbers in relatively safe regions of Ukraine.

Climate change poses significant challenges to Ukrainian livestock farming, impacting both animal health and productivity. Rising temperatures cause metabolic disruptions in livestock, leading to heat stress and increased susceptibility to diseases. This results in reduced productivity and higher veterinary costs. Additionally, ensuring an adequate supply of drinking water is becoming more difficult due to changing precipitation patterns. To mitigate these effects, it is essential to adapt livestock management practices. This includes improving housing conditions to reduce heat stress, ensuring reliable water sources, and selecting heat-tolerant and disease-resistant livestock breeds. Policy support and educational initiatives for farmers are also crucial to enhance resilience against climate impacts. Developing and implementing these strategies is vital for maintaining the sustainability and productivity of livestock farming in Ukraine [23,24].

Conclusions and prospects for further research

The current disruptions in export channels due to the conflict present a unique opportunity for biofuel start-ups in Ukraine to utilize animal fats as a feedstock for biofuel production. With an abundance of animal fats available, redirecting them towards domestic biofuel production can significantly reduce waste and provide a sustainable energy source. Focusing on second-generation biofuels allows start-ups to leverage advanced technologies to produce cleaner and more efficient fuels, aligning with global sustainability trends and enhancing energy independence. Developing a local biofuel industry can stimulate economic growth, create jobs, and reduce Ukraine's reliance on imported fossil fuels. As international markets adjust to these disruptions, start-ups that capitalize on this opportunity can position themselves as key players in the evolving bioenergy landscape. Developing a network of facilities for processing and disposing of animal by-products, such as rendering plants, offers significant opportunities for private businesses in Ukraine. Investing in modern technologies can create efficient and environmentally friendly facilities, reducing waste disposal costs for livestock farms and meat processing plants. This investment can expand service markets by providing comprehensive waste management services to agricultural producers and processors.Using animal by-products as feedstock for producing biodiesel and other biofuels supports the growth of alternative energy in Ukraine. Developing and expanding rendering plants will also help mitigate environmental pollution risks, contributing to the sustainable development of regions. Private companies specializing in environmental technologies can benefit from participating in these projects. Furthermore, engaging in waste processing and disposal projects can provide access to government grants, support programs, and preferential financing, stimulating business growth in this sector. Large agricultural holdings and poultry farming plants that have shown resilience during conflict could benefit significantly from the vertical integration of collecting animal by-products and building rendering plants for their meat processing operations. By integrating animal waste disposal and recycling facilities, the holding can enhance its biofuel production capabilities. This vertical integration will streamline operations, reduce costs, and create a more sustainable business model. The growth of such enterprises can create new jobs, drive economic growth, and improve environmental conditions in Ukraine, making this an attractive area for private businesses. In conclusion, leveraging the surplus of animal fats for biofuel production presents a multifaceted opportunity for Ukraine. It addresses waste management issues, supports the renewable energy sector, and fosters economic resilience. Future research should focus on assessing the most efficient technologies, exploring market opportunities, and assessing the prospects of the production of green hydrogen in Ukraine for second-generation biofuels.

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ПІДПРИЄМНИЦЬКІ МОЖЛИВОСТІ ТА ВИКЛИКИ НА УКРАЇНСЬКОМУ РИНКУ БІОПАЛИВА: ВИКОРИСТАННЯ ТВАРИННИХ ЖИРІВ ДЛЯ СТАЛОЇ ЕНЕРГЕТИКИ

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У статті досліджено економічний потенціал українських приватних підприємств щодо використання тваринних жирів як сировини для виробництва біопалива першого та другого поколінь. Оскільки Україна прагне підвищити свою енергетичну безпеку та зменшити вплив на навколишнє середовище, тваринні жири, побічний продукт переробки м'яса, представляють перспективні можливості для інноваційних енергетичних рішень. У дослідженні оцінюється доступність ринку, економічна життєздатність та екологічні переваги, що надають перспективи для підприємств, які входять у цей сектор. У статті розглядається підприємницький аспект використання тваринних жирів як потенційної сировини для біодизельних заводів та відновлювальних дизельних установок, сталість та потенціал тваринних жирів у виробництві біопалива, дослідження ринку тваринних жирів України. У статті доведено, що українська молочна та м'ясна галузі сильно постраждали від війни. Постраждало близько 43% промислової великої рогатої худоби та 42% виробництва молока, зі значними втратами у Харківській, Сумській та Чернігівській областях. Зусилля з переселення збільшили поголів'я худоби в більш безпечних регіонах. М'ясна промисловість стикається з перебоями в ланцюжках поставок, пошкодженнями інфраструктури та зміною динаміки ринку через війну, що впливає як на виробництво, так і на дистрибуцію. Таким чином, поточні перебої в експортних каналах через війну надають унікальну можливість для стартапів з виробництва біопалива в Україні використовувати тваринні жири як сировину для виробництва біопалива. З великою кількістю доступних тваринних жирів перенаправлення їх на внутрішнє виробництво біопалива може значно скоротити відходи та забезпечити стійке джерело енергії. Зосередження уваги на біопаливі другого покоління дозволяє стартапам використовувати передові технології для виробництва чистішого та ефективнішого палива, що відповідає світовим тенденціям сталого розвитку та підвищує енергетичну незалежність. Розвиток місцевої біопаливної промисловості може стимулювати економічне зростання, створювати робочі місця та зменшувати залежність України від імпортованого викопного палива. У міру того, як міжнародні ринки пристосовуються до цих збоїв, стартапи, які використовують цю можливість, можуть позиціонувати себе як ключових гравців у мінливому біоенергетичному ландшафті. Розвиток мережі підприємств з переробки та утилізації побічних продуктів тваринного походження, відкриває значні можливості для приватного бізнесу в Україні. Інвестиції в сучасні технології дозволяють створювати ефективні та екологічно чисті об'єкти, знижуючи витрати на утилізацію відходів для тваринницьких ферм і м'ясокомбінатів.

Ключові слова: *підприємництво, сталий розвиток, стартап, бізнес, ринок, відновлювальна енергетика, друге покоління біопалива, Україна.*