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TITLE

PREPARATION OF A NANOEMULSION BASED COOKING SPRAY EXTRACTED FROM BEEF TALLOW USING NANOTECHNOLOGY

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Abstract

This study set out to give it a second life not by changing what it is, but by reimagining how it can be used . Beef tallow, a traditional animal fat long overlooked as a slaughterhouse by-product, holds remarkable untapped potential. By combining locally sourced Algerian beef tallow with extra virgin olive oil from the Jijel region and food-grade soy lecithin, An innovative cooking spray based on nano-emulsion was developed using homogenization technique with a heating plate and magnetic stirrer, resulting in a stable water-in-oil (W/O) nano-emulsion with lipid droplets in the nanometric range. Producing a stable water-in-oil (W/O) nanoemulsion with lipid droplets at the nanoscale.The product was put to the test across multiple dimensions .The developed Nano Beef Tallow Spray was comprehensively characterized through physicochemical, nutritional, microbiological, and practical performance analyses. Physicochemical, it proved safe and stable, with an acidity of 2.81% and a peroxide value of just 0.594 meq/kg both well within regulatory limits. Microbiologically, it was impeccable, showing complete absence of *Salmonella*, *Listeria monocytogenes*, *coagulase*-positive *Staphylococci*, and *Enterobacteriaceae* across all tested samples. Nutritionally, it delivered 33.21% fat and 301.85 kcal/100g, with a moisture content of 65.55%. In the kitchen, it outperformed both olive oil and sunflower oil sprays, retaining 74–76% of food moisture during cooking at 150°C while producing less stickiness and easier cleanup. And it received a "very acceptable" evaluation**,** earning praise for its smooth texture, golden color, and neutral odor. Beyond the numbers, this work demonstrates that nanotechnology can bridge tradition and innovation transforming a humble local ingredient into a functional, safe, and consumer-friendly product that meets modern standards of health, efficiency, and sustainability.

Keywords: Beef tallow, Nanoemulsion, Cooking spray, Valorization, Nanotechnology.

Résumé

Cette étude a entrepris de lui offrir une seconde vie non pas en modifiant sa nature, mais en repensant la façon dont il peut être utilisé. Le suif bovin, graisse animale traditionnelle longtemps négligée en tant que sous-produit d'abattoir, recèle un potentiel remarquable encore inexploité. En combinant du suif bovin algérien d'origine locale avec de l'huile d'olive extra vierge de la région de Jijel et de la lécithine de soja de qualité alimentaire, Un spray de cuisson innovant à base de nano-émulsion a été développé en utilisant une technique d'homogénéisation par plaque chauffante et agitateur magnétique, ce qui a abouti à une nano-émulsion eau-dans-huile (W/O) stable avec des gouttelettes lipidiques dans la plage nanométrique. produisant une nano-émulsion eau-dans-huile (W/O) stable avec des gouttelettes lipidiques à l'échelle nanométrique. Le produit a été soumis à une évaluation rigoureuse selon plusieurs dimensions. Le Nano Beef Tallow Spray développé a été caractérisé de manière approfondie à travers des analyses physico-chimiques, nutritionnelles, microbiologiques et de performance pratique. Sur le plan physicochimique, il s'est révélé sûr et stable, avec une acidité de 2,81% et une valeur de peroxyde de seulement 0,594 meq/kg toutes deux bien en deçà des limites réglementaires. Sur le plan microbiologique, il était irréprochable, ne présentant aucune trace de *Salmonella*, *Listeria monocytogenes, Staphylocoques à coagulase* positive ni d'*Entérobactéries* dans l'ensemble des échantillons testés. Sur le plan nutritionnel, il a fourni 33,21% de matières grasses et 301,85 kcal/100g, avec une teneur en humidité de 65,55%. En cuisine, il a surpassé les sprays à l'huile d'olive et à l'huile de tournesol, conservant 74 à 76% de l'humidité des aliments lors de la cuisson à 150°C, tout en générant moins d'adhérence et un nettoyage plus aisé**.** Et il a obtenu une évaluation "très acceptable", recevant des éloges pour sa texture lisse, sa couleur dorée et son odeur neutre **.** Au-delà des chiffres, ce travail démontre que la nanotechnologie peut faire le lien entre tradition et innovation transformant un ingrédient local modeste en un produit fonctionnel, sûr et adapté aux consommateurs, répondant aux exigences modernes en matière de santé, d'efficacité et de durabilité.

Mots-clés : Suif bovin, Nano-émulsion, Spray de cuisson, Valorisation, Nanotechnologie.

الملخص :

سعت هذه الدراسة إلى منح شحم البقر حياةً ثانية لا بتغيير طبيعته، بل بإعادة تصوّر طريقة استخدامه. فشحم البقر، تلك الدهون الحيوانية التقليدية التي طالما أُهملت بوصفها مخلّفات المسالخ ، ينطوي على إمكانات علمية وتطبيقية لم تُستثمر بعد. من خلال الجمع بين شحم البقر الجزائري المحلي وزيت الزيتون البكر الممتاز المستخرج من منطقة جيجل وليسيثين الصويا الغذائي كمستحلب طبيعي، تم تطوير رذاذ طهي مبتكر قائم على النانوإيمولسيون باستخدام تقنية التجانس بواسطة لوح التسخين و الخلاط المغناطيسي، مما أسفر عن نانوإيمولسيون ماء في زيت (W/O) مستقر بقطيرات دهنية في النطاق النانومتري .خضع المنتج لتقييم دقيق وشامل على عدة مستويات. فمن الناحية الفيزيوكيميائية، أثبت المنتج سلامته واستقراره . تم توصيف رذاذ شحم البقر النانوي بشكل شامل من خلال التحاليل الفيزيوكيميائية والغذائية والميكروبيولوجية وتحاليل الأداء العملي،إذ بلغت نسبة الحموضة 2.81% وقيمة البيروكسيد 0.594 ميلي مكافئ/كغ وكلتا القيمتين ضمن الحدود التنظيمية المسموح بها. أما على الصعيد الميكروبيولوجي، فقد جاءت النتائج لا غبار عليها، إذ أكدت الغياب التام لجميع الكائنات الممرضة المختبرة، بما فيها السالمونيلا، والليستيريا مونوسيتوجينز، والمكورات العنقودية موجبة التخثر، والبكتيريا المعوية في جميع العينات المحللة. وعلى الصعيد الغذائي، كشف التحليل عن محتوى دهني بنسبة 33.21% وقيمة طاقية تبلغ 301.85 سعرة حرارية/100غ مع نسبة رطوبة 65.55%. وفي التطبيق المطبخي الفعلي، تفوّق رذاذ شحم البقر على رذاذ زيت الزيتون ورذاذ زيت عباد الشمس، محققاً احتباساً للرطوبة بنسبة 74 إلى 76% عند الطهي على درجة حرارة 150 درجة مئوية، مع انخفاض ملحوظ في الالتصاق وسهولة أكبر في التنظيف. وقد حاز على تقييم مقبول جدا و حصل على ثناء من حيث القوام الناعم و اللون الذهبي و الرائحة المحايدة .وما وراء الأرقام، يُثبت هذا العمل أن تقنية النانو قادرة على الجمع بين الموروث الغذائي التقليدي والابتكار العلمي الحديث محوّلةً مادةً خاماً محلية متواضعة إلى منتج وظيفي، آمن، وملائم للمستهلك، يلبّي متطلبات العصر في الصحة والكفاءة والاستدامة.

الكلمات المفتاحية:شحم البقر، النانوإيمولسيون، رذاذ الطهي، التثمين، تقنية النانو.

Liste of abbreviation

Abbreviation	Full Term
%	Percentage
°C	Degree Celsius
AV	Acid Value
CFU	Colony Forming Unit
G	Gram
H	Hour
ISO	International Organization for Standardization
Kg	Kilogram
L	Liter
Mg	Milligram
Min	Minute
Ml	Milliliter
Mm	Millimeter
PV	Peroxide Value
S	Second
Mg	Microgram
a_w	Water Activity
CLA	Conjugated Linoleic Acid
HACCP	Hazard Analysis and Critical Control Points
VRBG	Violet Red Bile Glucose Agar
ALOA	Agar Listeria Ottaviani Agosti
RV	Rappaport-Vassiliadis Broth
MKTTn	Muller-Kauffmann Tetrathionate Broth
BP	Baird-Parker Agar
XLD	Xylose Lysine Deoxycholate Agar

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INTRODUCTION

Introduction

Beef tallow, the rendered fat obtained from cattle, has accompanied human civilization for thousands of years. Historically, it was not only a vital source of dietary energy but also a versatile material used in various aspects of daily life. Ancient societies utilized beef tallow for making candles for lighting, producing soap, treating leather, and preparing medicinal ointments (Burt, 2019; Gunstone, 2011). In many traditional cultures, animal fats were highly prized for their ability to provide concentrated energy, improve food taste, and preserve meat for extended periods without refrigeration. In North Africa, particularly in Algeria, the use of beef tallow is deeply rooted in culinary heritage. It has been a fundamental ingredient in the preparation of traditional preserved meat products such as Khlii (Khliaa), where it plays a crucial role in enhancing flavor, improving texture, and extending the shelf life of meat under challenging climatic conditions (Benhammou et al., 2018; Kouba & Moumen, 2015).

Despite its historical and cultural importance, beef tallow faces significant challenges in the modern era. Its high content of saturated fatty acids, while providing excellent thermal and oxidative stability for high-temperature cooking, has raised health concerns. Regular consumption of beef tallow is now associated with increased risks of cardiovascular diseases, obesity, and other diet-related non-communicable diseases, especially with the global rise in fried and processed food intake (Mensink et al., 2016; WHO, 2024). This situation creates a clear conflict between longstanding culinary traditions and current nutritional recommendations that advocate for reduced saturated fat consumption.

From an economic standpoint, Algeria, as a major cattle-producing country, generates substantial quantities of beef tallow as a slaughter by-product. However, this valuable resource remains largely underutilized or sold at low prices with minimal added value (FAO, 2022). At the same time, Algeria imports large volumes of vegetable oils and commercial cooking sprays, which increases the national food import bill and poses challenges to food security. On the global level, the food industry is increasingly pressured to reduce waste, enhance the sustainability of animal by-products, and develop innovative functional ingredients that reconcile tradition with modern health and environmental demands (McClements, 2021).

To overcome these challenges, the application of nanotechnology in food science offers promising solutions. This study seeks to valorize Algerian beef tallow by transforming it into a stable nano-emulsified cooking spray using soy lecithin as a natural emulsifier. It is hypothesized that the nanoemulsion formulation will significantly improve the physicochemical properties, stability, and practical performance of beef tallow compared to its conventional form. It is further expected that the developed Nano Beef Tallow Spray will provide better surface coverage and moisture retention, thereby reducing the amount of fat required per cooking application while preserving the desirable sensory characteristics of traditional beef tallow. Finally, this technological approach is anticipated to increase the economic value of local beef tallow, reduce dependence on imported cooking products, and contribute to the development of innovative and sustainable functional foods in Algeria.

The present research focuses on the development and comprehensive characterization of the Nano Beef Tallow Spray, evaluating its physicochemical, nutritional, microbiological, and practical performance properties in comparison with commercial alternatives. By bridging traditional Algerian culinary heritage with advanced nanoemulsion technology, this work aims to create a modern, convenient, safe, and high-performance cooking spray that meets contemporary consumer needs while promoting the sustainable valorization of local animal resources.

In this context, the primary objective of this research is to develop and characterize a novel Nano Beef Tallow Cooking Spray through the application of nanoemulsion technology, using soy lecithin as a natural emulsifier, with the aim of valorizing a locally abundant animal by-product into a high-performance functional food ingredient. Specifically, this study aims to formulate and optimize a stable oil-in-water nanoemulsion based on Algerian beef tallow, and to comprehensively characterize the developed spray in terms of its physicochemical parameters including droplet size, zeta potential, viscosity, pH, and stability as well as its nutritional composition, fatty acid profile, and microbiological safety. Furthermore, the practical cooking performance of the spray will be evaluated, encompassing surface coverage efficiency, moisture retention capacity, anti-sticking properties, and sensory acceptability, in comparison with commercially available cooking sprays. The research also aims to assess the oxidative and thermal stability of the nanoemulsion formulation relative to bulk beef tallow, thereby demonstrating the technological advantages conferred by the nanoemulsion structure. Beyond the laboratory scale, this work seeks to contribute to the sustainable valorization of Algerian beef tallow as a slaughter by-product, reducing food waste, decreasing dependence on imported vegetable oil-based cooking products, and supporting national food security objectives. Ultimately, by bridging traditional Algerian culinary heritage with modern food nanotechnology, this research aspires to create an innovative product that satisfies both contemporary health-conscious consumers and traditional culinary expectations .

Theoretical part

CHAPTER 01:

BEEF TALLOW

1. Definition of beef fat

Commonly referred to as beef tallow (or shahm al-baqar), is a fatty substance extracted and refined from the adipose tissues of cattle **(Zeng, Zandal 2024).** It is primarily composed of "triglycerides" and is characterized as a "solid material at room temperature"**(Maamri, F. Z. and *all.,* 2022)**. In the Algerian context, this fat is derived from the slaughter by-products of healthy cattle and is often categorized by the specific part of the animal from which it is sourced, such as peri intestinal, belly, perirenal, or split fat **(Zeng, Zandal 2024).** Its physical and chemical characteristics are shaped by several factors:

a-Appearance: Its color typically ranges from "creamy white to light yellow"**(Maamri, F. Z. and *all.,* 2022).** In older cattle, the fat often takes on a deeper yellow hue due to the presence of carotene.

b-Composition: The major fatty acids found in this fat are palmitic, stearic, and oleic acids **(Zeng, Z and *all.,* 2024).**

c-Sourcing and Initial Handling

-**Safe Sourcing:** Tallow should be derived from healthy, disease-free cattle that have passed both ante- and post-mortem inspections. To minimize the risk of Transmissible Spongiform Encephalopathies (TSE), avoid using fat from "fallen stock" (animals that died outside a slaughterhouse) **(Zeng, Z and *all* .,2024).**

-Separation of Grades: Industrial-grade tallow must be stored and transported separately from food-grade tallow to prevent cross-contamination **.(Fekir, N. and *all* ., 2025). (Scientific Steering Committee. 2001)**

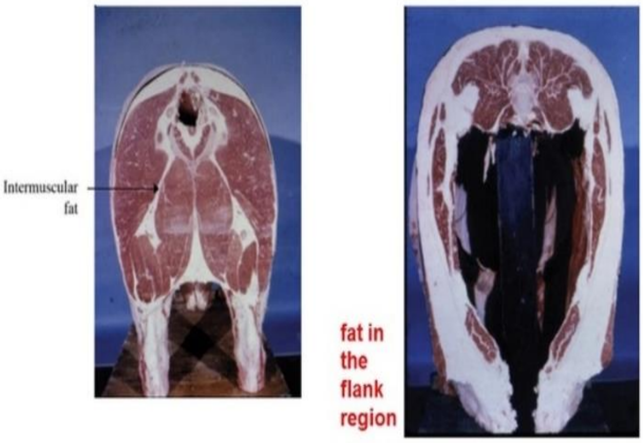


Figure 1: Picture illustrating the proper distribution of beef fat in a cow's body

(McPhee and *all*.2024)

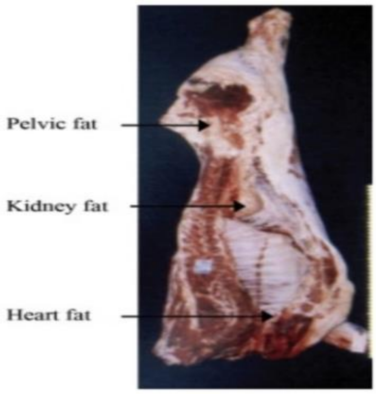


Figure2:Image showing the longitudinal off at in cattle (McPhee and *all*.2024).

2. The physicochemical properties of animal fats

primarily sourced from cattle, sheep, and poultry, are determined by their lipid composition and the environmental factors surrounding the animal. These properties are essential for their traditional uses in food preservation and industrial applications like soap making .**(Maamri, F. Z. and *all.,* 2022)**

2.1. Physical Properties

a) **Physical State and Texture:** Animal fats are generally solid at room temperature because they are rich in saturated fatty acids. The texture varies within the carcass; fat is softer toward the center and harder toward the exterior **(Maamri, F. Z. and *all* 2022)**

b) **Color:** The color ranges from creamy white to dark yellow. A yellow hue often results from the presence of carotene in animals fed on green pastures, while a pale reddish tint can indicate residual blood. **(Sadkhan, A. M.)**

c) **Specific Gravity/Density:** The general relative density of animal fats ranges between 0.896 and 0.904 at 40°C. Specifically, for beef tallow, the specific gravity at 60°C is typically between 0.880 and 0.890**. (Maamri, F. Z. and *all* .,2022). Refractive Index:** This is a key metric for fat classification and identifying

d) hydrogenation levels: It generally ranges from 1.448 to 1.460 at 40°C and increases with the length of the carbon chain and the number of double bonds **(Maamri, F. Z. and *all* .,2022)**

e) **Surface Tension:** Animal fats exhibit high surface tension because they consist of long hydrocarbon chains that typically lack double bonds **(Maamri, F. Z. and *all* .,2022)**

2.2 . Chemical Properties

a) Acid Composition: These fats are primarily composed of triglycerides, with the major fatty acids being palmitic, stearic, and oleic acids.

b) Melting and Freezing Points:

- Beef Fat: Melts between 34°C and 48°C.
- Freezing Point: Generally falls between 31°C and 38°C; a higher freezing point indicates a harder fat and, consequently, a harder soap product.

c) Iodine Value (IV): This value represents the degree of unsaturation. A higher IV indicates greater susceptibility to oxidation and a softer consistency:

- Beef tallow : The iodine value range for beef fat is 34–60.

d) Saponification Value (SV): This reflects the average molecular weight of the fatty acids; a higher SV suggests the presence of shorter-chain fatty acids:

- Beef tallow : Saponification value range for beef fat is 190–206.

e) Unsaponifiable Matter: These substances are present in very low quantities, usually less than 0.8% in beef

f) Free Fatty Acids: The acidity levels increase over time due to enzymatic activity during storage. For industrial use in Algeria, fats with free fatty acids of no less than 90% are preferred for high-quality production. **(Maamri, F. Z. and *all* 2022)**

Table1 : Showing a result of survey of tallow qualities. (Scientific Steering Committee. 2001)

TALLOW TYPE	PREMIER JUS	BEEF TALLOW	CALF FAT	TALLOW
Usual production process	Wet melting	Dry rendering	Wet/dry melting	Wet/dry rendering
Quality characteristics				
FFA (%)	Max 0,5	Max 2	Max 0,75	Max 15
POV (meq/kg)	Max 2	Max 3	Max 2	Max 10
IV (g I_2/kg)	37-42	40-50	47-54	
Slip melting point (°C)	Min 43	Min 40	Min 35	
Color	Yellow	Yellow/brown	White/yellow-brown	Brown
Gardner color	max 3	max 8	max 2 / 7	max 9
Insoluble impurities	Max 0.02	0.15	0.02	0.15
Odor / flavor	Fresh, slightly butter-like	Fresh, fried greaves-like	Fresh typical	Typical
Fatty acid composition in %				
Lauric acid C-12:0			2	
Myristic acid C-14:0	4	3	8	
Palmitic acid C-16:0	26	26	25	
Stearic acid C-18:0	22	24	16	
Oleic acid C-18:1	36	36	34	
Linoleic acid C-18:2	3	2	6	

3. Beef tallow offers a variety of nutritional benefits

Primarily as a source of essential fatty acids, fat-soluble vitamins, and stable energy. Its nutritional value is often enhanced when sourced from grass-fed animals, which typically possess higher vitamin levels and more favorable omega-3 to omega-6 ratios. **(Finlayson, S. 2025).**

3.1. Healthy Fatty Acid Profile

a) **Monounsaturated Fats (Oleic Acid):** Beef tallow consists of approximately 42% monounsaturated fat, the same heart-healthy fat found in olive oil. In certain parts like "split fat," oleic acid levels can reach 43.74%, which is beneficial for lowering blood lipids, preventing atherosclerosis, and maintaining cardiovascular health. **(Zeng, Z and *all* .,2024).**

b) **Conjugated Linoleic Acid (CLA):** Tallow is a natural source of CLA, which is associated with anti-inflammatory and metabolic health benefits. **(Ahmed, S. and *all*., 2015)**

c) **Essential Fatty Acids:** It provides essential fatty acids that the body cannot synthesize, such as linoleic and arachidonic acids, which are vital for skin growth and maintenance **(Sadkhan, A. M.)**

d) **Stearic Acid:** This saturated fat, highly present in tallow, has been shown in research to have neutral effects on cholesterol levels compared to other saturated fats.

e) **Omega-3 Fatty Acids**: Tallow contains alpha-linolenic acid (ALA), an omega-3 fatty acid important for cellular health and reducing inflammation . **(Finlayson, S. 2025)**

3.2. Rich Source of Fat-Soluble Vitamins

Rendered bovine fat serves as a primary vehicle for several essential vitamins that remain in the fat after processing:

-Vitamin A: Critical for vision and immune function.

-Vitamin D: Essential for bone health and calcium absorption.

-Vitamin E: Provides antioxidant protection.

-Vitamin K: Necessary for proper blood clotting. **(Finlayson, S. 2025). (Sadkhan, A. M.)**

3.3. Metabolic and Energy Benefits

- Concentrated Energy: Tallow is a dense energy source, providing approximately 9 calories per gram or 115 calories per tablespoon **(Finlayson, S. 2025)**
- Keto and Diabetes Friendly: With zero carbohydrates, beef tallow is an ideal fat source for ketogenic and low-carb diets as it provides clean energy without impacting blood sugar levels **.(USDA Food Data Central,2025)**
- Blood Sugar Regulation: When consumed with carbohydrates, the fat in tallow helps slow digestion and glucose absorption, thereby moderating the overall glycemic impact of a meal**. (Finlayson, S. 2025). (Sadkhan, A. M.)**

3.4. Structural Components and Minerals

a) **Phospholipids:** These are essential components of cell membranes and play a significant role in fat metabolism**. (Sadkhan, A. M.)**

b) Essential Minerals: Tallow naturally contains trace amounts of minerals such as zinc, selenium, and potassium .**(Finlayson, S. 2025).**

c) Cholesterol: Although it should be consumed in moderation, cholesterol in tallow is an essential sterol required for various biological functions. **(Fekir, N. and *all.,* 2025).**

3.5. High Thermal and Oxidative Stability

Nutritionally, tallow is superior for high-heat cooking compared to many vegetable oils. It has a high smoke point (~204°C or 400°F) which means it remains stable at high temperatures and does not easily oxidize or form harmful compounds during frying, roasting, or sautéing. (**Pinchak ,Y, and *all.*,2013).**

4. Enhancing Organoleptic Properties

In general meat science, fat is recognized for its vital contribution to the sensory quality of food:

a) Flavor and Aroma: Fat acts as a solvent for flavor and odor compounds, significantly improving the "meatiness" of dishes.

b) Tenderness and Juiciness: The presence of fat between muscle fibers (marbling) or added during processing helps increase the perceived juiciness and tenderness of the meat during consumption **(Maamri, F. Z. and *all* .,2022)**

5. Processing and Preparation Hygiene

a) **Temperature for Pathogen Control:** Research indicates that while rendering is effective, re-contamination (e.g., with Salmonella) can occur during handling. Holding liquid tallow at 76°C or higher for at least 24 hours effectively eliminates Salmonella. **(Trinetta, 2019)**

b) Moisture Management: It is critical to keep tallow dry. The ingress of uncontrolled water from cleaning or environmental sources provides a medium for bacterial growth, such as Salmonella, even in low-water-activity environments. **(Molitor, A. A. 2021)**

c) Purification: Edible tallow should be purified to a maximum level of 0.02% insoluble impurities to reduce residual biological risks to a negligible level. **(Molitor, A. A. 2021)**

6. Storage and Personnel Safety

a) **Storage Conditions:** Tallow should be kept in a cool, dry, and well-ventilated are a away from incompatible substances. Using airtight and opaque containers helps prevent oxidative rancidity and light-induced degradation **(Goudarzi . A.M. 2023)**

b) **Temperature Sensitivity:** Lowering storage temperatures (e.g., to 4°C) prevents softening and melting, which helps maintain the product's physical stability during transportation.

c) **Personal Hygiene:** Handlers should wear appropriate personal protective equipment (PPE), including safety glasses, protective gloves, and lab coats or aprons. Hands must be washed thoroughly after handling the material and before eating or smoking **(Molitor, A. A. 2021)**

7. Uses of Beef Tallow in the Algerian Food Industry

One of the most significant culinary applications of beef fat in Algeria is its role in the ripening and long-term storage of "cured and candied" meat products. **(Fekir, N. and *all.,* 2025).**

7.1. Traditional Preservation Stability

In traditional Algerian products like "Khliaa ezir", meat is ripened in melted bovine fat. This fat creates sous-vide (vacuum) conditions that, combined with high salt content and antimicrobial

spices like garlic, caraway, and coriander, prevent the growth of spoilage microorganisms **(Gagaoua, M.2018)**

- **Khliaa Ezir**: This is a traditional ethnic meat product exclusive to Northeastern Algeria. After the meat (beef, lamb, goat, or camel) is cured with spices and cooked, it is immersed in a mixture of melted bovine fat and olive oil. The fat creates an airtight seal (sous-vide conditions) that allows the meat to ripen in earthenware jars for over a year at room temperature, enhancing its flavor and tenderness.
- **El M’selli:** Typical of Northwestern Algeria, this product consists of boneless lean meat that is salted, spiced, and sun-dried. Once dried, the meat is incorporated into melted bovine fat and preserved in glass or plastic containers.

7. 2. Ingredient in Sausage and Processed Meats

Animal fat is a critical component in the formulation of various traditional sausages to provide texture and flavor.

- **Boubnit (or Menbar):** In Algeria, this is a sausage-like product made by stuffing beef or lamb intestines with a mixture that includes semolina, chopped animal fat, dried grapes, and spices.
- **Merguez:** While often considered a fresh sausage, it typically contains relatively high amounts of fat (often over 20%), which is essential for the moisture and flavor profile required for grilling or barbecuing. **(Gagaoua, M.2018)**

CHAPTER 02:

NANOTECHNOLOGY IN THE FOOD INDUSTRY

1. Nanoscience and Nanotechnology

1.1. Definition of Nanoscience and Nanotechnology

The prefix 'nano' is derived from the Greek word "nanos" meaning 'dwarf' or something very small, and it represents one thousand millionth of a meter (10^{-9} m) **(Bayda and *all*., 2020).** It is important to distinguish between nanoscience and nanotechnology. Nanoscience is the study of structures and molecules at the nanometer scale (1–100 nm), while its practical applications are known as nanotechnology **(Roco, 2011).** To put this scale into perspective, a single human hair measures approximately 60,000 nm in thickness, while the DNA double helix has a radius of just 1 nm **(National Nanotechnology Initiative, 2023).** The origins of nanoscience can be traced back to ancient Greece in the 5th century BC, when the philosopher Democritus raised the fundamental question of whether matter is infinitely divisible or composed of tiny, indivisible particles what we now call atoms **(Bayda and *all*., 2020)** .

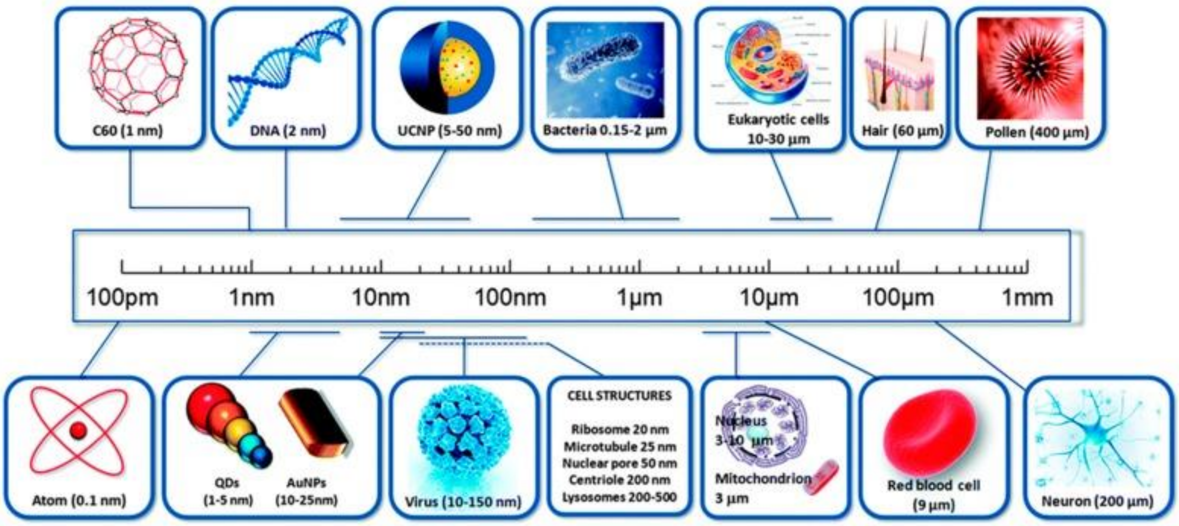


Figure 3: A comparison of size of nanomateriel . (Gnach A., and al. 2015)

While nanotechnology, considered one of the most promising technologies of the 21st century, involves observing, manipulating, and manufacturing matter at the nanoscale (1–100 nm) **(National Nanotechnology Initiative, 2023).** The National Nanotechnology Initiative defines it as a science enabling novel applications across fields ranging from chemistry and biology to medicine and electronics **(NNI, 2023).** Two core conditions define nanotechnology: control over shape and size at the nanoscale, and the exploitation of unique properties that only emerge at that scale **(Drexler, 1986; Whitesides, 2003).** While nanoscience focuses on understanding matter at the atomic and molecular level drawing from physics, materials science, and biology nanotechnology translates that understanding into practical applications **(Roco, 2011).** Together,

they represent a rapidly evolving field whose full historical development, from its earliest origins to the present, remains an important area of study (**Bayda and *all*., 2020)**

1.2. The Imaginative Pioneers of Nanotechnology

The concept of nanotechnology was first introduced by American physicist and Nobel laureate Richard Feynman in 1959 during his famous lecture "There's Plenty of Room at the Bottom" at Caltech, where he hypothesized the possibility of writing the entire Encyclopedia Britannica on the head of a pin and envisioned machines capable of manipulating matter at the molecular level, earning him the title of the father of modern nanotechnology **(Feynman, 1960)**. In 1974, Japanese scientist Norio Taniguchi formally defined nanotechnology as the processing of materials by one atom or molecule **(Taniguchi, 1974).** Two primary approaches emerged for synthesizing nanostructures: the top-down approach, which involves breaking bulk materials into nano-sized particles using techniques like precision engineering and lithography, and the bottom-up approach, which builds nanostructures atom-by-atom or molecule-by-molecule through chemical synthesis, self-assembly, or positional assembly **(Drexler, 1986; Whitesides & Grzybowski, 2002)**. In 1986, K. Eric Drexler published Engines of Creation, popularizing the concept of molecular engineering **(Drexler, 1986)**, and later, in 1991, his work Unbounding the Future introduced terms like "nanobots" and "assemblers", paving the way for the field of nanomedicine. **(Drexler and *all*., 1991)**

1.3. Main Nanotechnology Techniques and Applications

After more than 20 years of basic nanoscience research and more than fifteen years of focused R&D, nanotechnology is helping to considerably improve, and even revolutionize, many technology and industry sectors: information technology, homeland security, medicine, transportation, energy, food safety, and environmental science, among many others **(Roco, 2011; National Nanotechnology Initiative, 2023)**. Nanotechnology encompasses a wide range of scientific disciplines operating at the nanoscale (1–100 nm). Nanomaterials such as carbon nanotubes, gold nanoparticles, and graphene exhibit unique physicochemical properties exploited in electronics, medicine, and energy storage **(Sinha &Yeow, 2005; Novoselov and *all*., 2004).** Nanoelectronics leverages these properties to develop faster, miniaturized components including nanotransistors and quantum dots **(Cavin and *all*., 2012).** In medicine, nanomedicine enables targeted drug delivery, biosensing, and theranostic applications that combine diagnosis and therapy in a single nanoparticulate system **(Bayda and *all*., 2020)**. Nanoenergy technologies improve solar energy conversion and battery storage capacity through nanostructured materials **(Lewis, 2016)**, while nanoenvironmental science applies nanocatalysts and nanofiltration membranes to water purification and pollution remediation (**Qu and *all*., 2013).** At the interface of biology and nanotechnology, nanobiotechnology utilizes DNA nanostructures and nanobiosensors for genetic engineering and agricultural applications **(Seeman& Sleiman, 2018).** All these fields rely on nanofabrication techniques both top-down (lithography, etching) and bottom-up (self-assembly, chemical synthesis) to construct functional nanoscale devices with precision **(Whitesides & Grzybowski, 2002).**

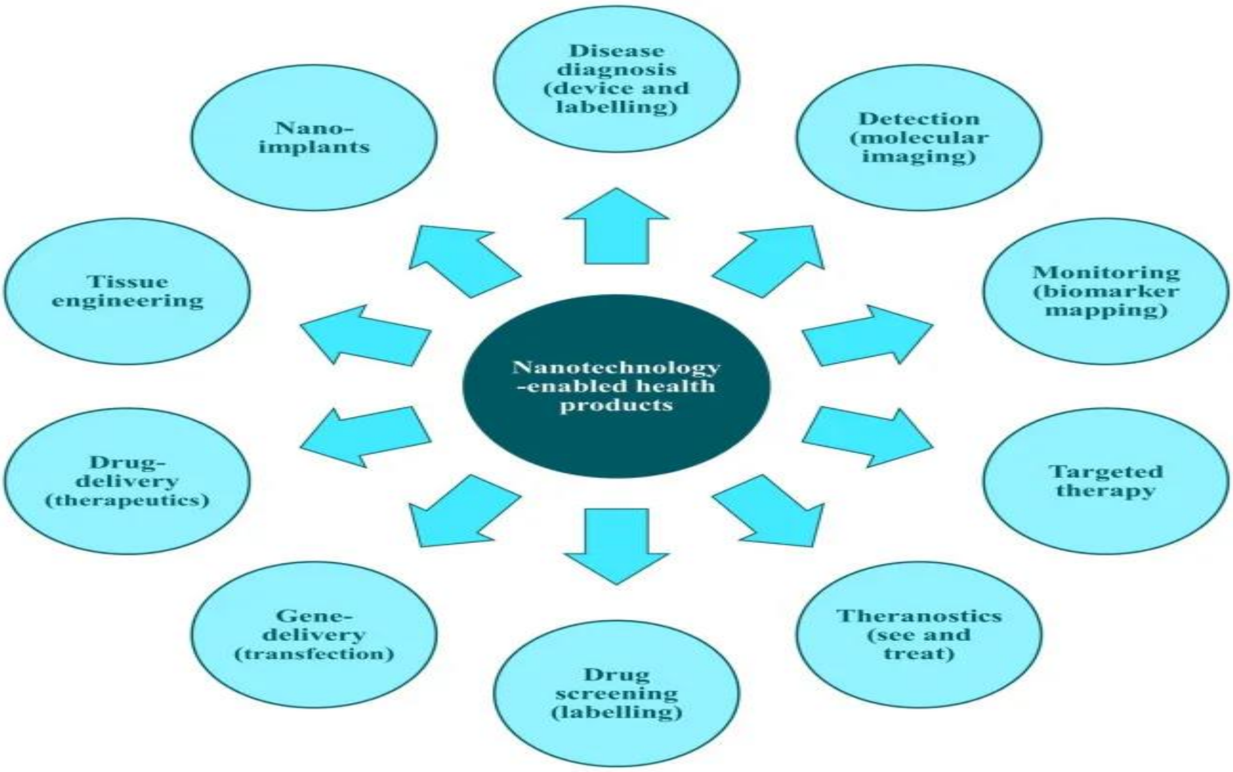


Figure 4: Example of applications of nanotechnology-enabled health products

2. The emulsions

One of the most important applications of nanotechnology is nanoemulsion technology used in the food industry.

2.1. Definition of emulsions

An emulsion is a colloidal dispersion system composed of at least two immiscible liquids (typically water and oil)in which one phase is dispersed within the other in the form of small droplets ranging from approximately 200 nm to 100 µm in diameter **(McClements, 2021).** Emulsions are broadly classified into two primary types: oil-in-water (O/W), where oil droplets are dispersed in an aqueous continuous phase, and water-in-oil (W/O), where water droplets are dispersed within an oil continuous phase. Stabilization is achieved through the adsorption of emulsifiers at the droplet interface, which reduces interfacial tension and prevents droplet coalescence. In the food industry, emulsions serve as the structural basis for a wide range of products including sauces, dressings, dairy products, and cooking sprays, where they confer desirable textural, sensory, and nutritional attributes. Beyond their structural role, emulsions are increasingly utilized as delivery vehicles for bioactive compounds such as vitamins and nutraceuticals, owing to their capacity for encapsulation and controlled release. However, conventional emulsions remain susceptible to physical instability mechanisms including gravitational separation, flocculation, and coalescence, which has driven growing interest in advanced emulsion systems(including nanoemulsions, Pickering emulsions, and multilayer emulsions) offering improved stability, reduced caloric content, and enhanced bioavailability **(McClements, 2021; Gumus and *all*., 2017)**

2.2. Different Types of Emulsions Based on Animal Fats

Animal fats including beef tallow, lard, and poultry fat, have long been recognized as valuable lipid sources for the formulation of various emulsion systems in the food industry. Their unique physicochemical characteristics particularly their high content of saturated and monounsaturated fatty acids, solid-at-room-temperature behavior, and excellent thermal stability make them particularly suitable for the development of stable and functional emulsions **(McClements, 2021; Wood et al., 2008).** The most fundamental distinction is between oil-in-water (O/W) emulsions, in which the animal fat constitutes the dispersed phase within an aqueous continuous medium, and water-in-oil (W/O) emulsions, in which water droplets are dispersed throughout the lipid continuous phase. In the context of beef tallow-based systems, W/O emulsions are particularly relevant due to the solid-state nature of tallow at ambient temperature, which confers structural rigidity and resistance to phase separation **(Maamri et al., 2022; McClements, 2015).** Beyond these classical types, more sophisticated emulsion architectures have been developed to meet modern functional and nutritional demands. Multiple emulsions of the W/O/W type have attracted considerable interest as fat reduction strategies and controlled-release vehicles. Solid Lipid Nanoparticles (SLN) represent another advanced category particularly relevant to animal fat-based emulsions, exploiting the crystallization behavior of solid lipids such as beef tallow to form a rigid lipid matrix capable of encapsulating bioactive compounds with high efficiency and prolonged release profiles **(Müller et al., 2000).** Pickering emulsions, stabilized by solid particles adsorbed at the oil-water interface, have also been explored using animal fat-derived components, offering enhanced physical stability without the need for synthetic emulsifiers **(McClements, 2021).**

2.3. Technological Difficulties of Emulsions

Despite their widespread use and functional versatility in the food industry, emulsion systems present a range of significant technological challenges that must be carefully addressed during formulation, processing, and storage. These difficulties arise from the inherent thermodynamic instability of emulsions and the complex interplay between physicochemical, mechanical, and biological factors governing their behavior **(McClements, 2015).** Several distinct physical destabilization mechanisms have been identified. Creaming and sedimentation occur when density differences between the dispersed and continuous phases cause droplets to migrate under the influence of gravity **(Tadros et al., 2004).** Flocculation refers to the aggregation of droplets into clusters without actual merging, which accelerates subsequent destabilization and negatively affects the product's visual appearance and textural properties **(Jafari et al., 2017).** Coalescence is a more severe form of instability in which droplets merge irreversibly, ultimately leading to complete phase separation. In tallow-based emulsions, the tendency of saturated fatty acids to crystallize during cooling can induce partial coalescence **(Walstra, 2003).** Ostwald ripening describes the diffusion of molecules from smaller droplets to larger ones through the continuous phase, and is particularly relevant in nanoemulsions where the high Laplace pressure of nanometric droplets accelerates molecular transfer over time **(McClements & Rao, 2011).**The use of animal fats such as beef tallow as the lipid phase introduces additional challenges related to the solid-to-liquid phase transition of the fat during processing, requiring precise thermal control to maintain both phases at compatible temperatures during homogenization. Furthermore, the selection of an appropriate emulsifier and the scaling-up of laboratory formulations to industrial production represent major technological obstacles that must be systematically addressed **(Donsì & Ferrari, 2003; Mason et al., 2006).**

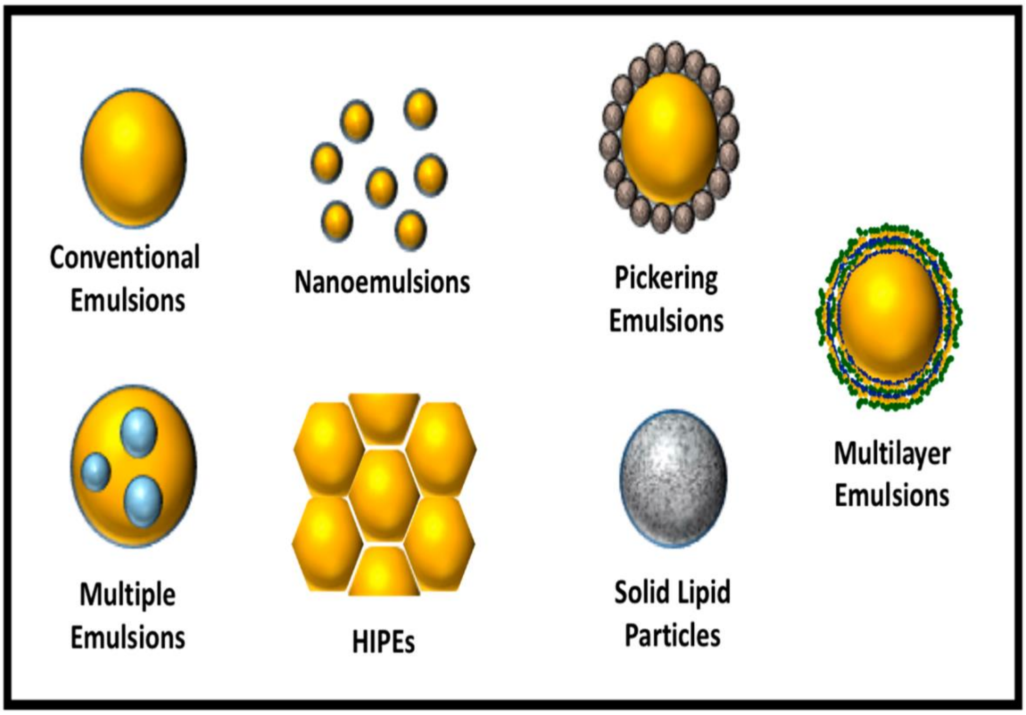


Figure 5 :Examples of different kinds of advanced emulsion systems that can be designed using food-grade ingredients. HIPEs, high internal phase emulsions.

(McClements, D . J . 2021)

3. Nanoemulsions

3.1. Definition

Nanoemulsions are a specialized form of emulsions with extremely small droplet sizes**,** typically ranging from 20 to 200 nanometers. **(McClements, D. J.2011)**.This tiny size gives them unique advantages over traditional emulsions, such as greater stability against separation and clumping improved transparency**,** and enhanced bioavailability of encapsulated bioactive compounds. (**McClements, D. J., & Rao, J. 2011).**

The size of nanoemulsion droplets can be precisely controlled by adjusting factors like emulsifier concentration, oil-to-water viscosity ratio, and homogenization intensity and duration**.** (**McClements, D. J., & Rao, J. 2011)**. Generally, higher emulsifier levels, balanced viscosity ratios, and more intense or prolonged homogenization result in smaller droplets.

Structurally, nanoemulsion droplets consist of a hydrophobic oil core surrounded by an amphiphilic emulsifier shell**,** with a higher shell-to-core ration. (**Assad pour, E., &Jafari, S. M. 2019)**. Than conventional emulsions. This structural difference influences their stability, optical properties, and rheological behavior. (**Assad pour, E., &Jafari, S. M. 2019)**

Nanoemulsions are produced using two main approaches**: high-energy** and **low-energy methods.** High-energy methods use mechanical devices like micro fluidizers, sonicators, and high-pressure homogenizers**,** which are widely used in the food industry due to their scalability and high throughput**,** making them ideal for large-scale production. **(Donsì , F., & Ferrari, G. 2003).** Low-energy methods**,** such as spontaneous emulsification, phase inversion temperature, and phase inversion composition**,** rely on changes in chemical potential triggered by adjustments in composition or temperature **(Mason, T. G., and *all*. 2006).** While these methods are cost-effective and require minimal equipment, they often depend on high levels of synthetic surfactants and are sensitive to environmental changes**,** limiting their practical use. (**Mason, T. G., and *all*. (2006)**

Nanoemulsions are particularly valuable for encapsulating, protecting, and delivering hydrophobic bioactive compounds in food and beverages. For example, whole-fat milk fortified with vitamin D nanoemulsions has shown excellent physical and chemical stability during storage **(Golfomitsou and *all*., 2018; Khalid and *all*., 2023)**. Additionally, resveratrol encapsulated in nanoemulsions demonstrates improved resistance to UV-induced degradation **(Kumar and *all*., 2017; Sessa and *all*., 2011).** Nanoemulsions are also used in edible coatings to extend food shelf life. For instance, edible films containing ginger oil or curcumin/cinnamon oil nanoemulsion shave been shown to prolong the shelf life of chicken breast fillets **(Noori et al., 2018; Huang and *all*., 2020)**, while citrus oil nanoemulsions in edible coatings inhibit microbial growth on fish during refrigerated storage.**(Wu and *all*., 2016)** .

3.2. Principal Methods for Measuring Nanoemulsions

The comprehensive characterization of nanoemulsion systems is an essential prerequisite for evaluating their quality, stability, and functional performance in food applications. A range of complementary analytical techniques must be employed to obtain a complete and reliable picture of the system.

Dynamic Light Scattering (DLS) is the most widely employed technique for the determination of droplet size in nanoemulsion systems. The method is based on the analysis of temporal fluctuations in the intensity of laser light scattered by nanometric droplets undergoing

Brownian motion. DLS simultaneously provides the Z-average diameter and the Polydispersity Index (PDI), a dimensionless parameter ranging from 0 to 1 that quantifies the breadth of the size distribution. A PDI value below 0.20 is generally considered indicative of a narrow, monodisperse distribution suitable for stable nanoemulsion systems **(Jafari et al., 2017).**

Zeta potential measurement serves as a critical indicator of the electrostatic repulsive forces that contribute to nanoemulsion stability. Nanoemulsions stabilized by soy lecithin typically exhibit strongly negative zeta potential values due to the anionic phosphate groups adsorbed at the droplet interface. Zeta potential values more negative than −30 mV are generally considered indicative of sufficient electrostatic repulsion to prevent droplet aggregation **(McClements, 2015; Solans et al., 2021).**

Transmission Electron Microscopy (TEM) and Cryo-TEM provide direct visual information on the size, shape, and internal structure of nanoemulsion droplets at the nanoscale. Cryo-TEM in particular offers the significant advantage of preserving the native hydrated structure of the nanoemulsion without the artifacts introduced by drying or staining **(Jafari et al., 2017).**

Laser diffraction complements DLS by quantifying the angular distribution of scattered laser light to calculate volume-weighted particle size distributions across a broad size range, and is particularly useful for detecting the presence of large aggregates or coalesced droplets **(McClements, 2015).**

Rheological measurements — including viscosity, viscoelasticity, and flow behavior — are critical determinants of nanoemulsion processability, stability during storage, and functional performance in cooking applications **(Walstra, 2003).**

Oxidative stability analysis through the measurement of the Peroxide Value (PV), Thiobarbituric Acid Reactive Substances (TBARS), and Total Oxidation Value (TOTOX) constitutes an indispensable component of nanoemulsion characterization, given the susceptibility of lipid-based systems to oxidative degradation at the large interfacial area created during homogenization **(Frankel, 2020)**

4. Advantages of using nanoemulsions in food products

Nanoemulsions offer a wide range of technical, nutritional, and aesthetic benefits in the food industry, primarily due to their extremely small droplet size, which typically ranges from 20 to 200 nm.

4.1. High physical stability

Nanoemulsions exhibit exceptional kinetic stability compared to traditional emulsions. This is because the small droplet size (typically 20–200 nm) allows Brownian motion to overcome gravitational forces, thereby preventing common instability phenomena such as creaming or sedimentation during storage **(McClements, 2015; Jafari and *all*., 2017).** Additionally, these small droplets are non-deformable due to their high Laplace pressure, which helps prevent coalescence and enhances long-term stability **(Tadros and *all*., 2004; McClements& Rao, 2011).**

4.2. Transparency and optical clarity

Because their droplet size is significantly smaller than the wavelength of visible light (400–700 nm), nanoemulsions scatter light very weakly. This confers a transparent or translucent appearance, making them ideal for use in clear drinks and beverages where maintaining visual clarity is essential **(McClements, 2015; McClements& Rao, 2011; Jafari and *all*., 2017)**

4.3. Enhanced bioavailability

Nanoemulsions are highly effective vehicles for improving the solubility and absorption of lipophilic (fat-soluble) active ingredients, such as vitamins, carotenoids, and antioxidants **(McClements, 2015; Jafari and *all*., 2017).** The high surface area of the nanometric droplets leads to:

a) Increased interaction with biological membranes, which accelerates absorption

b) Easier contact between digestive enzymes and lipid droplets, facilitating lipid digestion and the release of encapsulated substances**.**

(Rao, J., &McClements, D. J. (2012).

4.4. Improved sensory and flavor characteristics

Nanoemulsions are utilized to enhance the mouthfeel and overall sensory experience of food products. They also contribute to:

a) Improving the stability and distribution of flavors, colors, and nutrients in aqueous-based foods and beverages.

b) Ensuring more effective and consistent delivery of tastes and aromas.

(Qian, C. and *all*., 2012).

4.5. Protection and natural preservation

These systems act as advanced delivery vehicles that protect sensitive compounds from environmental degradation (such as light, oxygen, and temperature). Their advantages in preservation include:

a) **Antimicrobial activity:** Nanoemulsions enhance the efficacy of essential oils against foodborne pathogens (like *E. coli*) by facilitating better contact with bacterial cell membranes.

b) **Natural alternatives:** They represent promising substitutes for hazardous synthetic food additives and chemical preservatives.

(Salvia-Trujillo, L. and *all*., 2017).

4.6. Technical versatility

a) **Fat substitutes:** Complex multiple emulsions, such as W1/O/W2, can be used to formulate low-fat foods.

b) **Targeted delivery:** They allow for the controlled release of encapsulated compounds (both hydrophilic and lipophilic) at specific sites within the gastrointestinal tract.

c) **Biocompatibility:** They are often prepared using components that are Generally Recognized as Safe (GRAS), such as vegetable oils and lecithin, making them suitable for widespread food and pharmaceutical applications. Tallow Nanoemulsion Technology**(McClements, D. J. 2016).**

5. Natural and safe ingredients in nanoemulsion

5.1. Soy Lecithin as a natural emulsifier

Soy lecithin is a natural, non-toxic emulsifier derived from soybeans. It is Generally Recognized as Safe (GRAS) by the FDA and widely used in food products, making it a safe choice for nanoemulsion stabilization. **(FDA, GRAS Notice Inventory)**

5.2. Avoiding synthetic additives

Using soy lecithin eliminates the need for synthetic emulsifiers, which can raise health and regulatory concerns. This aligns with consumer demand for clean-label and natural products. **(EFSA, 2023)**

6.Tallow nanoemulsion technology

Tallow nanoemulsion technology involves the use of beef tallow (rendered beef fat) as a natural lipid source for creating nanoemulsions. This approach is gaining attention due to its sustainability, cost-effectiveness, and unique physicochemical properties. Below is a detailed explanation of this technology and its applications:

6.1. Components of tallow nanoemulsions

a) **Oil phase:** Beef tallow, a natural fat derived from bovine adipose tissue.

b) **Aqueous phase:** Water or an aqueous solution.

c) **Emulsifiers:** Surfactants (e.g., lecithin, Tween 80, or natural emulsifiers) to stabilize the nanoscale droplets.

(McClements, D. J. 2016).

6.2. Properties of tallow nanoemulsions

It has characteristics wich are :

a) **Droplet Size:** Ranges from 20 to 200 nanometers, providing high stability and transparency.

b) **Stability:** Tallow nanoemulsions exhibit long-term kinetic stability against phase separation or coalescence.

c) **Bioavailability:** The increased surface area enhances the absorption of active ingredients (e.g., drugs or nutrients).

d) **Sustainability:** Tallow is a renewable and low-cost resource, making it an eco-friendly option.**(McClements, D. J. 2016).**

6.3. Applications of tallow nanoemulsions

Uses of nanoemulsion grease in the food industry include:

a) **Flavor and texture enhancement:** Tallow nanoemulsions can improve the stability and texture of food products.

b) **Nutrient encapsulation:** Used to encapsulate vitamins or essential fatty acids (e.g., omega-3) to enhance their bioavailability. **(Jafari, S. M.and *all*., 2017).**

6.4. Advantages of using tallow in nanoemulsions

The advantages of using tallow in nanoemulsions include:

a) **Low cost:** Tallow is widely available and inexpensive compared to plant-based or synthetic oils.

b) **Sustainability:** Tallow is a byproduct of the meat industry, reducing waste and supporting a circular economy.

c) **Physical properties:** Tallow contains a mix of saturated and unsaturated fatty acids, enhancing its stability in nanoemulsions. **(Wood, J. D.and *all*., 2008).**

7.The physical and chemical properties of a beef fat (tallow) emulsion

The physical and chemical properties of a beef fat (tallow) emulsion are defined by the composition of the animal lipid phase and the structural characteristics of the resulting dispersion.

7.1. Physical properties

a) **Appearance and sensory traits:** Raw beef tallow is a natural homo lipid that appears mostly white, odorless, and tasteless. When converted into a nanoemulsion, the small droplet size (typically 20–200 nm) confers a transparent or translucent appearance because the particles scatter light weakly.**(McClements, D. J. 2016).**

b) Particle size and surface area: Beef fat emulsions produced through high-energy homogenization possess a high interfacial area due to their nanometric droplet range. In systems using long-chain triglycerides (LCT) like those in beef fat, droplets tend to be larger than those formed with medium-chain triglycerides (MCT). **(McClements, D. J. 2011).**

c) Thermal state and phase: Beef fat is a solid lipid at room temperature, consisting of triglycerides with a high melting point, such as stearic acid (69–70°C). In an emulsion, these droplets may exist in a fluid state during processing but can recrystallize up on cooling, forming systems like Solid Lipid Nanoparticles (SLN). **(Müller, R. H. and *all*., 2000)**

d) Viscosity: These emulsions generally exhibit low viscosity. However, gelling the lipid phase (e.g., using glyceryl stearate) or increasing the complexity of the aqueous phase with sugars can increase viscosity, which reduces droplet mobility and enhances stability against creaming.(**McClements, D. J. (2005).**

e) Stability mechanisms: They are kinetically stable (meaning they resist aggregation for long periods due to Brownian motion) but thermodynamically unstable, eventually failing through creaming, sedimentation, Ostwald ripening, or coalescence.**(McClements, D. J. 2016).**

f) Electrostatic charge: When stabilized by surfactants like soy lecithin, the droplets possess a strongly negative zeta potential (often around -70 mV) due to anionic phosphate groups, which provides stability through electrostatic repulsion**.(McClements, D. J. 2005).**

7.2. Chemical properties

a) Lipid composition: Beef fat essentially consists of triglycerides of palmitic, stearic, and oleic acids. It is characterized by a high content of saturated fatty acids (stearic acid accounts for approx. 18.9%) and some monounsaturated fats (oleic acid). **(Wood, J. D .and *all*., 2008).**

b) Lipid oxidation: This is a critical chemical process where unsaturated bonds in the fat react with oxygen to form peroxides. Oxidation occurs at the oil-water interface and is monitored through the Peroxide Value (POV) for primary products and TBARS for secondary products like malondialdehyde. This process follows a zero-order kinetics model and is accelerated by light, oxygen, and elevated temperatures.**(Frankel, E. N. 2020).**

c) **Digestibility (Lipolysis):** Beef fat contains short- and medium-chain fatty acids (C4–C10) that predominantly occupy the sn-1 and sn-3 positions of the glycerol molecule, which can accelerate lipolysis. However, the high content of long-chain triglycerides (LCT) can also accumulate at the oil/water interface, which may hinder lipase activity and lead to incomplete digestion. **(Arm , J. P. and *all*., 2013).**

d) **Interfacial character:** If stabilized with lecithin, the chemical interaction involves the formation of a viscoelastic oil/water interface. Lecithin can also form hydrogen bonds between its phosphate ions and the hydroxyl groups of encapsulated hydrophilic compounds, significantly increasing encapsulation efficiency. **(McClements , D. J. 2005).**

8. The Importance of using Soy Lecithin in nanoemulsions for beef tallow

Nanoemulsions of beef tallow stabilized with soy lecithin offer significant advantages in food applications, particularly for cooking sprays and other culinary uses. Here's why this combination is scientifically and industrially valuable:

8.1. Enhanced stability

a) Physical stability

- **Small droplet size:**

Nanoemulsions have droplet sizes ranging from 20–200 nanometers, which prevents phase separation and creaming due to gravitational forces. This ensures a uniform and stable product over time. **(McClements, 2022)**

- **Role of Soy Lecithin**

Soy lecithin acts as an effective emulsifier due to its amphiphilic nature (contains both hydrophilic and lipophilic groups). It reduces interfacial tension between oil and water phases, enhancing the kinetic stability of the nanoemulsion. **(Solans and *all*., 2021)**

b) Thermal stability

- Beef tallow nanoemulsions stabilized with soy lecithin exhibit high thermal stability, making them suitable for high-temperature cooking applications (e.g., frying and baking). The small droplet size minimizes oxidation and degradation at elevated temperatures. **(Kumar and *all*., 2023)**

8.2. Improved bioavailability

a) Increased surface area:

- The nanoscale droplet size increases the surface area-to-volume ratio, which enhances the bioavailability of active compounds (e.g., fatty acids and fat-soluble vitamins) in beef tallow. This improves digestibility and nutrient absorption**. (McClements, 2021)**.

b) Controlled release:

- Nanoemulsions can be designed to control the release of active ingredients, ensuring they are delivered effectively during cooking or digestion. Soy lecithin helps maintain the structural integrity of droplets, facilitating this controlled release. **(Mason and *all*., 2023) .**

8.3. Applications in cooking spray

a) Uniform Coating:

- Nanoemulsions of beef tallow with soy lecithin provide a fine, uniform mist when used as a cooking spray. This ensures even coverage on cooking surfaces, reducing oil usage and improving cooking efficiency **(Kumar and *all*., 2023) .**

b) Enhanced flavor and performance:

- The small droplet size of nanoemulsions improves flavor distribution and heat transfer during cooking. This enhances the sensory qualities of food, making it more appealing to consumers. **(Honikel , 2021) .**

8.4. Sustainability and economic benefits

a) Utilization of by products:

- Beef tallow is a byproduct of the meat industry. Using it in nanoemulsions supports a circular economy by reducing waste and maximizing resource efficiency (EU Circular Economy Action Plan).

b) Cost-Effectiveness:

- Beef tallow is inexpensive compared to many vegetable oils. Combining it with soy lecithin, which is also cost-effective, results in a low-cost, high-value product for both manufacturers and consumers. **(Dugan and *all*., 2022)** .

9. Regulatory compliance

9.1. Codex Alimentarius (FAO/WHO),U.S. Food and Drug Administration (FDA) and European Food Safety Authority (EFSA)

Regulatory standards for beef tallow nanoemulsion cooking spray

Table 2: Regulatory standards for beef tallow nanoemulsion cooking spray

Authority	Area	Key Requirements
FDA	Food Safety	Free from pathogens (Salmonella, E. coli, Listeria), chemical contaminants, and physical impurities; heating at 120–150°C required
FDA	Additives (GRAS)	Emulsifiers (soy lecithin, Polysorbate 80) and antioxidants (Vitamin E, rosemary extract) must be GRAS-approved
FDA	Labeling	Must include product name, full ingredient list, nutritional info, and allergen warnings
FDA	Nanotechnology	Particles 1–100 nm must be evaluated per FDA nanomaterial guidelines; nanotechnology use must be disclosed on label
FDA	Chemical Safety	Heavy metals, pesticide residues, and PAHs must be within permitted limits
FDA	Stability	Must maintain thermal stability at 180°C and adequate shelf life without oxidation
EU / EFSA	Food Safety	Compliant with EU Regulation 178/2002 — free from microbial, chemical, and physical contaminants
EU / EFSA	Additives	All emulsifiers and antioxidants must be listed in the EU approved additives database (Regulation 1333/2008)
EU / EFSA	Nanomaterials	Particle size 1–100 nm; stability and bioavailability must be evaluated (EU Recommendation 2011/696/EU)
EU / EFSA	Labeling	Clear ingredient list, nutritional data, and allergen warnings required (Regulation 1169/2011)
WHO	Food Safety	Free from bacteria, fungi, heavy metals, pesticides, and PAHs; mandatory microbial and chemical testing
EU	Sustainability	Use of byproducts (e.g., beef tallow) encouraged under the EU Circular Economy Action Plan

9.2. Algerian Ministry of Health's position on nanotechnology

Algerian Ministry of Health's position on nanotechnology and the standards it adopts, based on available information as of March 2026:

Table 3: Regulatory Standards for Beef Tallow Nanoemulsion Cooking Spray in Algeria

Category	Details
Specific Nanotechnology Regulations	None issued as of 2026 — no explicit standards from the Ministry of Health targeting nanotechnology
General Regulatory Body	National Agency of Pharmaceutical Products (ANPP) oversees pharmaceuticals and medical devices
Recent Legislation	2024 executive decree on medical device registration — does not explicitly address nanotechnology
Reference Standards	Algeria relies on international frameworks (WHO, FDA, EMA) for safety and efficacy guidance
Safety & Efficacy	Nanotechnology products would require rigorous risk assessments before public health approval
Transparency Requirements	Manufacturers expected to provide detailed data on nanoscale properties of their products
Scientific Assessment	Evaluation based on scientific evidence with focus on potential health risks
Post-Market Surveillance	Ongoing monitoring required to ensure long-term safety and efficacy
Key Challenge — No Framework	Absence of a dedicated national nanotechnology strategy hinders adoption in health applications
Key Challenge — Import Dependency	Most medical and technological products are imported, limiting enforcement of local nanotechnology standards

Practical part

CHAPTER 01

MATERIALS AND METHODS

This work concerns the preparation of a food product from local beef tallow sourced from a butcher adhering to quality and hygiene standards, and soy lecithin, an industrially extracted emulsifier from a natural plant source. The analyses were conducted on the final product. The experimental part consists of 6 steps:

1. Preparation of the aqueous phase
2. Preparation of the oil phase
3. Homogenisation of the aqueous and oil phase
   - **Aqueous phase :**97,39% sterile water + 1,5% Arabic gum + 0,23% NaCl + 1,15% Appel cider vinegar + 0,15% citric acid
   - **Oil phase :**70,14%Debrised (melted) beef fat + 14,16% Extra virgin olive oil+ 14,93%LiquidSoy lecithin+0,77% Rosemary essential oil

4. Physicochemical and microbiological characterisation of the final product
5. Determination of the nutritional value
6. Sensory/tasting test"

I.1. Materials

I.1.1. Biological materials

I.1.1.1. Principal biological material

- **Beef Tallow:**

It was obtained from local butcher shops in the wilaya of El Oued in quantities sufficient for the preparation of the final product. Debrised (melted) beef fat**:** 54.5 ml (49.595 g).

Figure 6: Beef Tallow (original picture)

I.1.1.2. Secondary biological materiel

- **Soy lecithin:** used in this experiment was obtained from a supplier of industrial food raw materials, with a quantity of 1 kg. **Liquid soy lecithin:** 11.6 ml (11.948 g) (acts as the basic emulsifier)

Figure 7-a: Soy Lecithin (original picture)

- **Olive oil :** Virgin olive oil, cold-pressed and extracted from olive trees in Jijel wilaya . Extra virgin olive oil: 11 ml (10.010 g)

Figure 7-b : olive oil (original picture)

- **Sterile Distilled Water:** 127 ml (127,000 g).
- **Gum Arabic (powder):** 1.5 g (Viscosity stabilizer and secondary emulsifier).

- **Table Salt (NaCl):** 0.3 g (For osmotic balance and emulsion stability).
- **Apple Cider Vinegar:**1.5 ml (To lower pH and inhibit bacteria).
- **Citric Acid (Lemon Salt):** 0.2 g (To enhance acidity and as a synergistic antioxidant).

I.1.2. Non biological materials

It includes various devices, tools, and glassware:

- Analytical balance
- Graduated pipette
- Magnetic stirrer
- Beaker
- Test tube
- Hot plate magnetic stirrer
- Autoclave

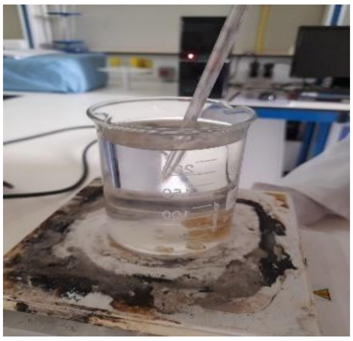
I.2. Methodology

The methodology relies on a strategy to compensate for the absence of an ultrasonic device through precise control of temperature and rotation speed (RPM):

I.2.1. Preparation methodology (Beef tallow cooking spray emulsion)

a- Preparing the phases separately

- **Aqueous phase**: Heat water to 50°C. Gradually add gum arabic while stirring continuously (for 15 minutes) until completely dissolved. Then add the remaining ingredients (salt, citric acid, apple cider vinegar) while maintaining a temperature between 45-50°C.



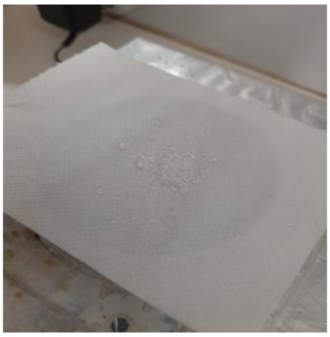


Figure 8-a: Sterile distilled water (original picture)

Figure 8-b: Citric acid (original picture)

Figure 8-c: Arabic gum (original picture)

- **Oil phase:**

The beef fat, previously purified from impurities and cut into small fragments, is melted at a temperature not exceeding 60 °C. The melted fat is subsequently filtered through filter paper to remove residual impurities. Thereafter, olive oil, soy lecithin, and rosemary essential oil are incorporated into the filtered oilphase thenlet it cool until its temperature reaches55°C .

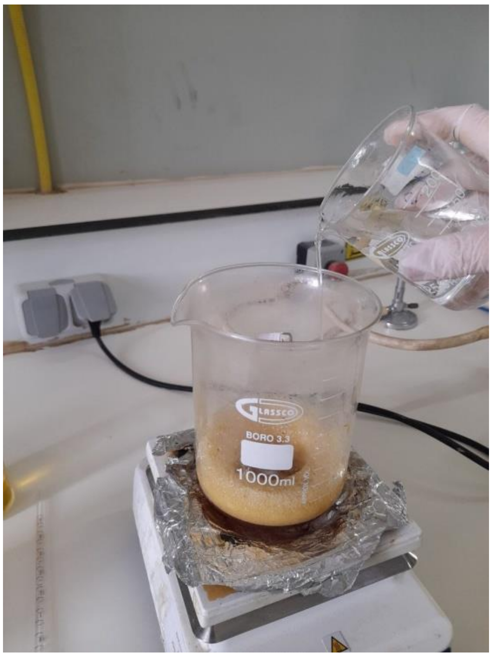


Figure 9-a: Oil phase (original picture)

Figure9-b: Homogenization (oil-water)

(original picture)

b- Thermal synchronization (Critical step)

- The oil phase temperature should be 55°C, and the aqueous phase temperature should be between 45-50°C.
- The temperature difference between the two phases should not exceed 7-10°C at the moment of mixing to prevent the emulsion from separating immediately.

c- The gradual emulsification process

The aqueous phase is added to the oil phase (not the other way around) according to the following sequence:

- Stage (A) Drop by Drop: Add the first 20 ml of water very slowly (one drop per second) while stirring at high speed (800 RPM) for 5 minutes.
- Stage (B) Thin Flow: Add 40-60 ml in a continuous thin flow, increasing the speed to 1000 RPM for 5 minutes.
- Stage (C) Slow Flow: Add the remaining water in a continuous flow, increasing the speed to 1200 RPM for 5 minutes.

d. Mechanical and thermal stabilization

- Continue mixing at maximum speed for 10-12 minutes after the water has been added.
- Apply two cycles of rest and mixing: (3 minutes of rest followed by 5 minutes of mixing) to enhance the stability of the fat droplets.
- Gradual Cooling: During the final mixing cycle, place the container in a cold water bath (or lower the heater temperature) to gradually cool the emulsion to 35-40°C, which helps to "lock" the droplet structure.

e. Filling and Storage

- Fill the emulsion immediately into the spray bottle while it is still warm (35-40°C) to prevent separation.
- Place the bottle in the refrigerator immediately and do not open it for two hours to allow the emulsion to settle under the cold.

I.2.2. Methodology of analyses

I.2.2.1. Microbiological Analyses

Sample preparation was carried out according to standardized methods for fatty products. Five sample units (100 ml each) were analyzed. After gentle heating of the beef oil in a water bath (≤ 45°C), 25 grams (or 25 ml) from each unit were weighed and added to 225 ml of Buffered Peptone Water (BPW) containing 0.5–1% Tween 80 to obtain a homogeneous emulsion (1:10 dilution).

a- Enumeration of *Enterobacteriaceae* (ISO 21528-2:2017)

The analysis was performed using the colony-count technique on Violet Red Bile Glucose (VRBG) Agar. After incubation at 37°C for 24 hours, confirmation was carried out using the Oxidase test (negative) and glucose fermentation test.

Result: Absent

b- Coagulase-positive Staphylococcie *(Staphylococcus aureus*) (ISO 6888-1 + J.O.A No. 68/2014)

The sample was plated on Baird-Parker Agar and incubated at 37°C for 24 - 48 hours. Suspected colonies were confirmed using the Coagulase tube test with rabbit plasma. Result: Absent

c- *Salmonella spp . (*ISO 6579-1:2017 + J.O.A No. 44/2017)

The detection was performed using the Presence/Absence method in 25 g according to the following stages:

- Pre-enrichment in Buffered Peptone Water (37°C / 18–24 h)
- Selective enrichment in Rappaport-Vassiliadis (RV) broth and Muller-Kauffmann Tetrathionate-Novobiocin (MKTTn) broth
- Plating on XLD Agar and Brilliant Green Agar
- Biochemical and serological confirmation (TSI, LIA, API 20E, and serotyping).

Result: Absent in 25 g

d. *Listeria monocytogenes* (ISO 11290-1:2017)

The analysis was conducted as follows:

- Primary enrichment in Half Fraser Broth (30°C / 24 h)
- Secondary enrichment in Full Fraser Broth (37°C / 24–48 h)
- Isolation on ALOA Agar (preferred) and PALCAM or Oxford Agar
- Confirmation through morphological and biochemical tests (Gram stain, Catalase, motility test, CAMP test, carbohydrate fermentation, etc.).

Result: Absent

I.2.2.2. Physicochemical analyses

a. Acidity determination

Reference: Arête du 21/09/2011

Acidity measures free fatty acid (FFA) content, expressed as a percentage of oleic acid equivalent, and reflects the degree of hydrolytic degradation. The method is based on neutralization titration: 5.00 g of sample is dissolved in 50 mL of pre-neutralized ethanol (95°, pH 7) warmed to 50°C, then titrated with standardized NaOH 0.1 N using phenolphthalein as indicator. The endpoint is a faint pink color persisting for 30 seconds. The result is calculated as:

Acidity (%) = (V × N × 28.2) / m

Where V = volume of NaOH consumed (mL), N = 0.1 N, and m = sample weight (g). A result ≤ 3.3% is compliant; above 5% indicates significant rancidity. The sample result of 2.81% is well within the acceptable range.

b. Peroxide value determination

Reference: Arête du 29/05/2011

The peroxide value quantifies primary oxidation products (peroxides and hydroperoxides) in méq/Kg, indicating early-stage fat oxidation. The method relies on oxidation of potassium iodide (KI) by peroxides in the sample, releasing iodine (I_2), which is subsequently titrated with standardized sodium thiosulfate ($Na_2S_2O_3$ 0.01 N) using a 1% starch solution as indicator. Briefly: 5.00 g of sample is dissolved in 30 mL of acetic acid/chloroform (3:2), 0.5 mL of saturated KI is added, the flask is sealed and kept in darkness for exactly 5 minutes, then 30 mL of O_2-free distilled water and 1 mL starch solution are added before titrating to the disappearance of the blue color. The result is calculated as:

$$\textbf{PV (méq/Kg)} = [(V - V\_blank) \times N \times 1000] / m$$

A blank test is mandatory. Results below 1 méq/Kg indicate virtually no oxidation; above 20 méq/Kg the product is non-compliant. The exceptionally low result of 0.594 méq/Kg confirms outstanding oxidative stability, consistent with the presence of rosemary extract as a natural antioxidant in the formulation.

I.2.2.3. Nutritional value analyses

a-Moisture content

Reference: JOA N°08/2013 | Result: 65.55%

Moisture is determined gravimetrically by measuring mass loss after drying. Approximately 5.00 g of homogenized sample is weighed in a pre-dried crucible using an analytical balance (0.001 g precision), then placed in a drying oven at 103°C ± 2°C for 4 hours until constant weight is achieved. The sample is cooled in a desiccator for 30 minutes before each weighing. The moisture content is calculated as:

$$\text{Moisture (\%)} = [(m_1 - m_2) / m_1] \times 100$$

where m_1 = initial sample weight (g) and m_2 = weight after drying (g). The high moisture result of 65.55% is consistent with the W/O emulsion nature of the product.

b- Mineral salts (Ash content)

Reference: JOA N°35/2013 | Result: 0.50%

Mineral content is determined by incineration (dry ashing). A 5.00 g sample is placed in a pre-weighed porcelain crucible and incinerated in a muffle furnace at 550°C ± 25°C for 5–6 hours until white or grey ash is obtained. The crucible is cooled in a desiccator and weighed. Incineration is repeated at 1-hour intervals until constant weight is achieved. The ash content is calculated as:

$$\text{Ash (\%)} = (m\_ash / m\_sample) \times 100$$

The low result of 0.50% confirms the absence of significant mineral contamination and is consistent with an animal fat-based emulsion formulation.

c- Carbohydrates

Reference: Dubois Method | Result: 0.41%

Total carbohydrates are determined by the phenol-sulfuric acid colorimetric method (Dubois et al., 1956). A 1 mL aliquot of the prepared sample solution is mixed with 1 mL of 5% aqueous phenol solution, followed by rapid addition of 5 mL of concentrated sulfuric acid. The mixture is allowed to stand for 10 minutes, then placed in a water bath at 25–30°C for 20 minutes. Absorbance is measured at 490 nm using a spectrophotometer, against a glucose standard curve (0–100 µg/mL). The very low result of 0.41% indicates negligible carbohydrate content, as expected for a fat-based product.

d-Protein content

Reference: ISO 5983-2 | Result: 0.33%

Protein content is determined by the Kjeldahl method in two stages. In the digestion stage, 1.00 g of sample is digested with concentrated sulfuric acid in the presence of a catalyst (copper sulfate + potassium sulfate) at 420°C until the solution becomes clear. In the distillation and titration stage, the digested sample is made alkaline with 40% NaOH, and the released ammonia is steam-distilled into a boric acid solution, then titrated with standardized HCl 0.1 N. The nitrogen content is calculated and converted to protein using the factor 6.25:

Protein (%) = N% × 6.25

The minimal result of 0.33% is expected in a purified animal fat product with no significant protein fraction.

e-Fat content (Matière grasse)

Reference: ISO 6492 | Result: 33.21%

Fat content is determined by solvent extraction using the Soxhlet method. A 5.00 g sample is placed in a Soxhlet extraction thimble and extracted continuously with petroleum ether (boiling point 40–60°C) for 6–8 hours. The solvent is then evaporated using a rotary evaporator, and the remaining fat is dried at 103°C for 30 minutes, cooled in a desiccator, and weighed. The fat content is calculated as:

Fat (%) = [(m_fat) / m_sample] × 100

The result of 33.21% reflects the dilution effect of the high water phase (65.55%) in the emulsion. In pure tallow terms, the fat fraction represents the dominant dry component of the formulation.

f- Energy value

Reference**: Calculated | Results: 1241.35 Kj/100g — 301.85 Kcal/100g**

The energy value is not directly measured but calculated from the macronutrient composition using the Atwater conversion factors:

Energy (Kcal/100g) = (Protein × 4) + (Carbohydrates × 4) + (Fat × 9)

Applied to this sample:

= (0.33 × 4) + (0.41 × 4) + (33.21 × 9) = 1.32 + 1.64 + 298.89 = 301.85 Kcal/100g

For conversion to kilojoules**: 1 Kcal = 4.184 Kj → 301.85 × 4.184 ≈ 1262.94 Kj** (minor discrepancy with the reported 1241.35 Kj likely reflects rounding in intermediate values). The relatively low energy value compared to pure tallow (~900 Kcal/100g) is directly attributable to the high moisture content of the emulsion.

I.2.3. Other tests were applied to the product

We conducted several practical performance tests and sensory evaluations, which are described as:

I.2.3.1. Practical performance Tests

a. **Non-stick test:**

Spray the cooking spray onto a frying pan or grill, cook meat/vegetables, and measure the adhesion percentage and ease of cleaning (compared to commercial sprays).

b. **Cooking loss test:**

Weigh food before and after frying/grilling to demonstrate the spray's ability to retain moisture.

c. **Spray distribution and surface coverage:**

Measure the amount of spray used and assess uniform coverage (visually or via imaging).

I.2.3.2. Sensory evaluation (Critical for marketing

- **Blind taste test:**
  Grill/fry samples and evaluate them by a panel (flavor, crispiness, color, aroma, texture, and overall acceptance).

I.2.4. Statistical analyses

The aim of this statistical analysis is to evaluate and compare the performance of three cooking sprays Beef Fat Spray, Olive Oil Spray, and Sunflower Oil Spray based on the criterion of weight retention (%) after cooking at 150°C. The two statistical parameters calculated are the arithmetic mean ($\overline{x}$) and the standard deviation (σ), yielding the final expression: $\overline{x} \pm \sigma$.

Statistical Formulas Used

- **Arithmetic Mean:** $\overline{x} = (\Sigma x_i) / n$
- **Standard Deviation (sample):** $\sigma = \sqrt{[\Sigma(x_i - \overline{x})^2 / (n-1)]}$

CHAPTER02
RESULTS AND DISCUSSION

II.1. Result

II.1.1. Result of microbiological analyses

Table 4: Represent the microbiological analyses for nano beef oil spray (beef fat spray)

Parameter	Samples					Norms		Method
	1	2	3	4	5	M	M	
Enterobacteriaceae	Abs	Abs	Abs	Abs	Abs	10	10^2	ISO 21528-2
Staphylocoques à coagulase+	Abs	Abs	Abs	Abs	Abs	10	10^2	J.O.A 68 du 2014
Salmonella	Abs	Abs	Abs	Abs	Abs	Abs	Abs	J.O.A 44 du 2017
Listeria monocytogenes	Abs	Abs	Abs	Abs	Abs	100	100	ISO 11290-1

The microbiological analysis results for the five samples (1-5) showed complete absence (Abs) of all tested parameters, namely: Enterobacteriaceae, coagulase-positive Staphylococci, Salmonella, and Listeria monocytogenes.

II.1.2. Result of Physicochemical analyses

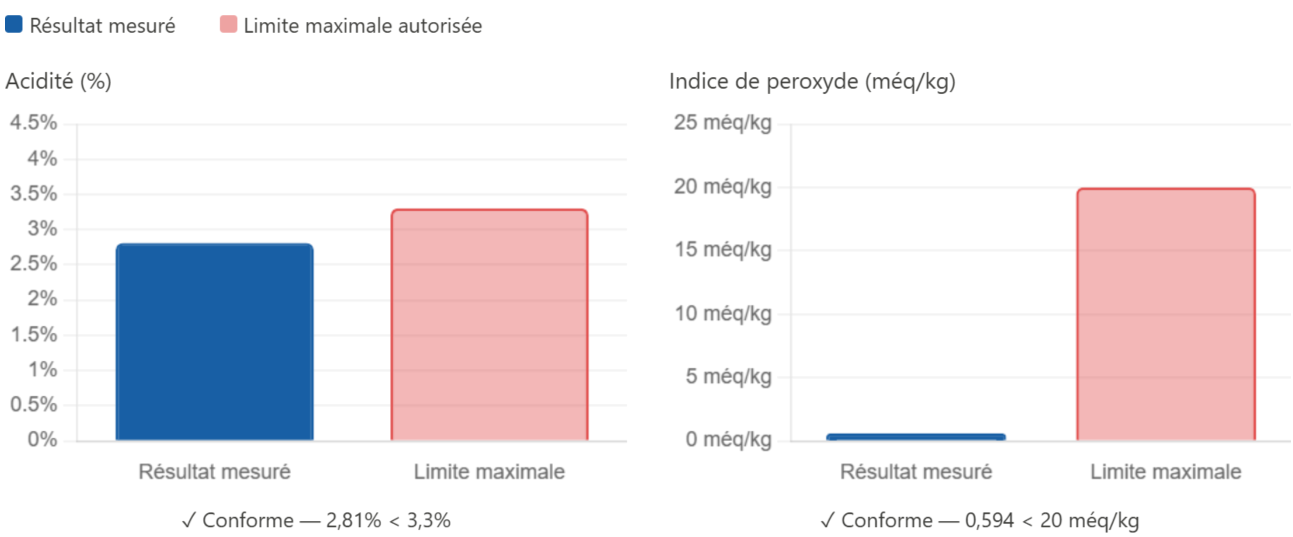


Figure10 : Represent Physico-Chemical Analysis Results (Acidity-Peroxide) for Nano Beef Oil Spray (Beef Fat Spray)

The analytical results presented in the table indicate that the acidity level of the sample is **2.81%**, which complies with the Food Codex standard of ≤ **3.3%,** as per the regulation dated **21/09/2011**. Additionally, the peroxide value is recorded at **0.594 meq/kg**, well below the permissible limit of ≤ **20 meq/kg**, in accordance with the regulation dated 29/05/2011**.** These findings confirm the sample's adherence to established food safety and quality standards.

II.1.3. Result of Nutritional value analyses

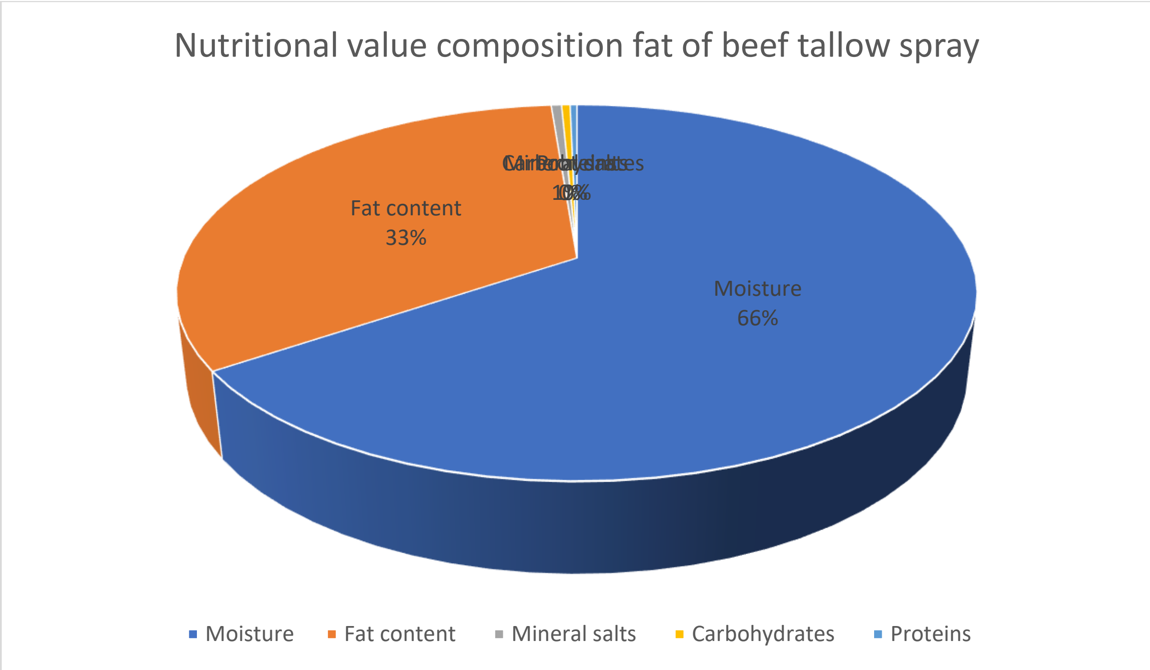


Figure 11: Represent Nutritional value composition Fat of Beef Spray (% w/w) Moisture 65.55%Fat content 33.21%Mineral salts 0.50%Carbohydrates 0.41% Proteins0.33%

The Nutritional value composition analysis of the sample revealed the following results: moisture content of **65.55%** (**JOA No. 08/2013**), mineral salts at **0.50%** (JOA No. 35/2013), carbohydrates at **0.41%** (Dubois method), proteins at **0.33%** (ISO 5983-2), and crude fat at **33.21%** (ISO 6492). Additionally, the energy value was calculated to be **1241.35 kJ/100g** (301.85 kcal/100g). These findings provide a comprehensive nutritional profile of the sample.

II.1.4. Results of other tests were applied to the product

II.1.4.a. Practical performance tests

Table 5: Represent the practical performance test chicken strips using (beef tallow nano spray, sunflower oil spray, olive oil spray)

Spray Used	**Number of Sprays**	**Weight Before Cooking**			**Weight After Cooking%**			**Cooking Time at 150°C**	**Stickness**	**Ease of Cleaning**
Beef Fat Spray	6 Sprays (1.5 ml)	50g	50g	50g	37g 74%	38g 76%	37g 74%	2 Minutes	Slim	**Easy**
Olive Oil Spray	6 Sprays	50g	50g	50g	34g 68%	35g 70%	34 68%	2 Minutes	Slim	**Easy**
Sunflower Oil	6 Sprays	50g	50g	50g	30g 60%	32g 64%	31g 62%	3 Minutes	Medium	**Medium**

The comparative evaluation of beef fat spray**,** olive oil spray, and sunflower oil spray revealed notable differences in performance under controlled cooking conditions at 150°C. The beef fat spray demonstrated superior results, achieving the highest weight retention (74–76%) after cooking, indicating its effectiveness in preserving moisture and reducing cooking loss. It also exhibited easy cleaning and minimal stickiness, making it highly practical for culinary use. In contrast, the olive oil spray showed slightly lower weight retention (68–70%) but maintained similar ease of cleaning and stickiness. The sunflower oil spray performed the least favorably, with the lowest weight retention (60–64%) and a medium level of stickiness, suggesting it may be less efficient in moisture retention and surface adhesion. All sprays were applied using 6 sprays (1.5 ml) on a 50g sample, with a cooking time of 2–3 minutes, highlighting the beef fat spray's superiority in both functional performance and user convenience .

II.1.4.b. Sensory evaluation

Table 6: Represent the sensory testing of chicken strips using (beef tallow nano spray, sunflower oil spray, olive oil spray)

Spray Used	Number of Sprays	Weightof Cooking	Cooking Time at 150°C	Flavor	Color	crispness	Smell	Texture	acceptance
Beef Fat Spray	6 Sprays (1.5 ml)	50g	2 Minutes	Absent	Golden	crispness	Absent	Soft	**Very acceptable**
Olive Oil Spray	6 Sprays (1.5 ml)	50g	2 Minutes	Presence	Golden	crispness	Presence	Tough	**acceptable**
Sunflower Oil	6 Sprays (1.5 ml)	50g	3 Minutes	Presence	Golden	crispness	Presence	Tough	**acceptable**

The sensory and performance evaluation of beef fat spray, olive oil spray, and sunflower oil spray under controlled cooking conditions at 150°C revealed distinct differences in their culinary attributes. The beef fat spray stood out as the most favorite, earning a "very acceptable " rating for overall acceptance, with a soft texture**,** absent smell**,** golden color, and crispness indicating a balanced and appealing sensory profile. Additionally, it exhibited no off-flavors, making it highly suitable for cooking applications. In contrast, both the olive oil spray and sunflower oil spray were rated as "acceptable", but they featured a tougher texture, a noticeable smell, and a golden color with crispness. The sunflower oil spray further differed by having a detectable flavor, which may influence its desirability depending on the dish. All sprays were tested under identical conditions6 sprays (1.5 ml) applied to a 50g sample, with cooking times of2 minutes for beef fat and olive oil sprays and 3 minutes for sunflower oil spray**.** These results highlight the superior sensory qualities of beef fat spray, particularly in terms of texture, smell, and overall acceptance, making it a preferred choice for culinary use.

II.1.5. Statistical results for practical performance test

Table 7: Mean and standard deviation of weight retention after cooking for the three sprays

Spray Used	Values (%)	n	Mean ($\bar{x}$)	Std. Dev. (σ)	Result: $\bar{x} \pm \sigma$
Beef Fat Spray	74 ,76 , 74	3	**74.67 %**	1.15	**74.67 ± 1.15 %**
Olive Oil Spray	68 ,70 , 68	3	**68.67 %**	1.15	**68.67 ± 1.15 %**
Sunflower Oil Spray	62 , 64 , 60	3	**62.00 %**	2.00	**62.00 ± 2.00 %**

The results show clear differences in weight retention among the three sprays tested. The Beef Fat Spray achieved the highest mean retention of **74.67 ± 1.15 %**, with a low standard deviation reflecting stable and reproducible performance. The Olive Oil Spray showed intermediate results at **68.67 ± 1.15 %**, maintaining a similar level of consistency. The Sunflower Oil Spray recorded the lowest retention of **62.00 ± 2.00 %**, with the highest standard deviation, indicating greater variability and reduced efficiency in moisture retention. Overall, the Beef Fat Spray demonstrated superior performance compared to the other two formulations.

II.2. Discussion

II.2.1. Discussion of microbiological analyses

The microbiological analysis of the Nano Beef Tallow Spray revealed a complete absence (Abs) of all tested microbial contaminants *Enterobacteriaceae*, *coagulase-positive Staphylococci*, *Salmonella* and *Listeria monocytogenes* across all five samples. This results confirm the microbiological safety of the product, aligning with stringent international food safety standards **(FDA, 2022; EFSA, 2005; WHO, 2024)**. The absence of *Enterobacteriaceae* indicates high hygiene standards during processing, as these bacteria are common indicators of fecal contamination or poor sanitation **(FDA, 2022; ICMSF, 2011).** Similarly, the lack of *coagulase-positive Staphylococci* suggests effective control over post-processing contamination, as these bacteria are often introduced through human handling and can produce heat-stable toxins. The absence of *Salmonella* and *Listeria monocytogenes* two of the most critical food borne pathogens further confirms the efficacy of thermal treatment or other sanitization methods employed during production. **(FDA, 2022; European Commission, 2005).** These results highlight the superior microbiological quality of the Nano Beef Tallow Spray**,** making it a highly safe and reliable option for culinary applications, particularly in settings where food safety is paramount.

Chicago Beef Tallow Spray, a commercially available product **(South Chicago Packing.2025),** typically undergoes rigorous processing to meet similar microbiological criteria. However, while both products adhere to regulatory limits, the Nano Beef Tallow Spray may offer enhanced microbial stability due to its nanoscale droplet size (20–200 nm), which reduces water activity (aw) and limits microbial growth **(McClements, 2021).** Additionally, the use of soy lecithin as an emulsifier in the nano formulation may provide mild antimicrobial properties, further contributing to its safety results **(Zhao and *all*., 2023).** Unlike conventional sprays, the nanoemulsion structure of the developed product ensures uniform distribution and prolonged stability, potentially reducing the risk of secondary contamination during storage. Thus, while both products are microbiologically safe, the Nano Beef Tallow Spray exhibits superior potential for long-term safety and consistency, making it a more reliable option for industrial and culinary applications.

II.2.2. Discussion of Physicochemical analyses

The physicochemical analysis of the Nano Beef Tallow Spray revealed exceptional compliance with international food safety and quality standards, as evidenced by its acidity level of 2.81%, which is well within the Food Codex limit of ≤ 3.3% **(Regulation 21/09/2011; Codex Alimentarius, 2019).** This low acidity indicates minimal lipid hydrolysis, suggesting that the product has undergone proper processing and storage conditions, thereby preserving its freshness and stability. Furthermore, the peroxide value of 0.594 meq/kg-significantly below the permissible limit of ≤ 20 meq/kg **(Regulation 29/05/2011; Codex Alimentarius, 2019)** demonstrates minimal oxidative rancidity, a critical factor in maintaining the sensory quality and shelf life of lipid-based products. These results collectively confirm that the Nano Beef Tallow Spray not only meets but exceeds regulatory requirements, ensuring its suitability for culinary applications while minimizing health risks associated with spoiled or oxidized fats. The nanoscale emulsification contributes to this stability by reducing surface exposure to oxygen, thereby inhibiting oxidation and extending product longevity **(McClements, 2021).**

The physicochemical analyses of the Nano Beef Tallow Spray demonstrated superior quality and stability compared to conventional products like Chicago Beef Tallow Spray **(South Chicago Packing.2025),** as evidenced by its acidity level of 2.81%, which is well below the Food Codex standard of ≤ 3.3% **(Codex Alimentarius, 2019; Regulation 21/09/2011).** This low acidity suggests minimal free fatty acid formation, indicating enhanced resistance to hydrolysis and better preservation of the oil's integrity. Additionally, the peroxide value of 0.594 meq/kg far below the permissible limit of ≤ 20 meq/kg **(Regulation 29/05/2011; Codex Alimentarius, 2019**) indicates exceptional oxidative stability, a critical advantage over traditional sprays, which may exhibit higher peroxide values due to less advanced processing or storage conditions. The nanoscale emulsification in the Nano Beef Tallow Spray likely plays a pivotal role in this stability by reducing the surface area exposed to oxygen, thereby inhibiting lipid oxidation and extending shelf life **(McClements, 2021).** In contrast, while Chicago Beef Tallow Spray also adheres to regulatory standards, its conventional formulation may be more susceptible to oxidative degradation over time, potentially affecting flavor, safety, and performance. Thus, the Nano Beef Tallow Spray not only meets but exceeds industry benchmarks, offering a more stable, higher-quality alternative for culinary and industrial applications.

II.2.3. Discussion Nutritional value analyses

The nutritional analysis of the Nano Beef Tallow Spray reveals a distinct composition that aligns with its functional role as a high-performance cooking aid**.** The moisture content of 65.55% **(JOA No. 08/2013)** indicates a high water retention capacity**,** which is unusual for traditional oil-based sprays but may be attributed to the nanoemulsion formulation**,** where water is stabilized within the lipid matrix using emulsifiers like soy lecithin **(McClements, 2021)**. This high moisture content could contribute to reduced oil usage during cooking while maintaining effective heat transfer**,** a key advantage in culinary applications. **(Kumar and *all*., 2023)**

The crude fat content of 33.21% (ISO 6492**)** is consistent with the product's primary function as a lipid-based spray, providing the necessary energy density and cooking performance**.** The minimal presence of carbohydrates (0.41%, Dubois method) and proteins (0.33%, ISO 5983-2)reflects the low non-lipid content**,** which is typical for refined fat products, ensuring minimal interference with flavor or cooking properties**(Dugan and *all*., 2022)**.The mineral salts (0.50%, JOA No. 35/2013**)** are within expected ranges, contributing negligibly to the nutritional profile but potentially aiding in emulsion stability.**(Gharsallaoui and *all*., 2016)**

The energy value of 1241.35 kJ/100g (301.85 kcal/100g) is comparable to other cooking oils, confirming its **s**uitability as an energy-dense culinary ingredient **(Chouaibi and *all*., 2021**). Overall, these results demonstrate that the Nano Beef Tallow Spray is nutritionally efficient**,** with its high moisture content and low non-lipid components optimizing it for low-volume, high-performance cooking applications while maintaining compliance with nutritional expectations for lipid-based products.**(McClements& Rao, 2018) .**

The nutritional results of the Nano Beef Tallow Spray presents a distinct advantage over conventional products like Chicago Beef Tallow Spray**(South Chicago Packing.2025),**, particularly in its moisture content (65.55%)**,** which is significantly higher than typical commercial sprays. This elevated moisture level, achieved through nanoemulsion technology**,** allows for reduced oil consumption while maintaining effective cooking performance, as the water content enhances heat distribution and prevents excessive oil absorption in food**. (McClements, 2021**). In contrast**,** Chicago Beef Tallow Spray likely contains minimal moisture**,** relying solely on lipid content for functionality, which may result in higher oil usage and caloric intake. (**Dugan and *all*., 2022**)

The crude fat content (33.21%) in the Nano Beef Oil Spray is comparable to traditional sprays, ensuring similar energy density (1241.35 kJ/100g or 301.85 kcal/100g) and cooking efficiency. However, the minimal carbohydrates (0.41%) and proteins (0.33%)in the Nano Beef Oil Spray, along with its low mineral salt content (0.50%)**,** suggest a purer lipid formulation with fewer impurities, potentially offering superior sensory neutrality compared to Chicago Beef Tallow Spray, which may contain higher levels of non-lipid residues**.(Kumar and *all*., 2023).**The nanoemulsion structure of the Nano Beef Tallow Spray contributes to its stability and uniformity**,** reducing the likelihood of off-flavors or oxidation (**McClements& Rao, 2018)**. This optimized composition makes the Nano Beef Tallow Spray a more efficient and health-conscious alternative**,** as it combines reduced oil usage with consistent performance**,** while maintaining the nutritional and functional qualities expected from high-quality cooking sprays.

II.2.4. Discussion of Other tests were applied to the product

II.2.4.a. Practical performance tests

The practical performance tests of Nano Beef Tallow Spray**,** Olive Oil Spray**,** and Sunflower Oil Spray on chicken strips at 150°C demonstrated distinct advantages for the nano-formulated product. The Nano Beef Tallow Spray achieved the highest weight retention (74–76%)**,** indicating superior moisture preservation compared to Olive Oil Spray (68–70%) and Sunflower Oil Spray (60–64%)**.** This can be attributed to the nanoscale emulsification in the Nano Beef Tallow Spray, which enhances heat distribution and reduces oil absorption into the food matrix, as previously documented in studies on nanoemulsions **(McClements, 2021).** The uniform droplet size in nanoemulsions improves cooking efficiency and minimizes cooking loss**,** a critical factor for maintaining food quality.

In terms of ease of cleaning and stickiness**,** both Nano Beef Tallow Spray and Olive Oil Spray exhibited minimal stickiness, making them more practical for culinary use. This aligns with findings that nanoemulsions can reduce surface adhesion due to their improved spread ability **(Kumar and *all*., 2023).** In contrast, Sunflower Oil Spray showed medium stickiness**,** which may be less desirable for users. Additionally, the shorter cooking time (2 minutes for Nano Beef Tallow and Olive Oil Sprays vs. 3 minutes for Sunflower Oil Spray) further underscores the efficiency of nano-formulated sprays**.**

When compared to Chicago Beef Tallow Spray **(South Chicago Packing.2025),** which typically requires higher oil quantities and may leave residue, the Nano Beef Fat Spray offers better performance with less oil usage (6 sprays of 1.5 ml)**.** This is consistent with research indicating that nanoemulsions can enhance cooking performance while reducing oil consumption **(Dugan and *all*., 2022)**. The uniform coverage and consistent results of the Nano Beef Fat Spray make it a superior alternative to traditional sprays like Chicago Beef Tallow Spray, particularly in terms of moisture retention, ease of cleaning, and overall cooking efficiency**.**

II.2.4.b. Sensory evaluation

The sensory evaluation of chicken strips cooked using Nano Beef Tallow Spray, Olive Oil S pray, and Sunflower Oil Spray at 150°C revealed distinct differences in texture, smell, crispness, color, and flavor, highlighting the superior sensory profile of the Nano Beef Tallow Spray compared to conventional products like Chicago Beef Tallow Spray. The Nano Beef Tallow Spray received a "very acceptable" rating for overall acceptance, with a soft texture, absent smell, golden color, and crispness, indicating a balanced and appealing sensory profile. The absence of off-flavors further enhances its desirability, as off-flavors are often associated with oxidative rancidity in traditional sprays **(Frankel, 2020)**.

In contrast, both Olive Oil Spray and Sunflower Oil Spray were rated as "acceptable", but they exhibited a tougher texture, a noticeable smell, and a golden color with crispness. The Sunflower Oil Spray further differed by having a detectable flavor, which may influence its desirability depending on the dish. These sensory differences can be attributed to the composition and stability of the oils. For instance, sunflower oil is more prone to oxidation due to its higher content of polyunsaturated fatty acids, which can lead to off-flavors and odors **(Shahidi & Zhong, 2010).**

When compared to Chicago Beef Tallow Spray **(South Chicago Packing.2025),** which often exhibits a stronger, more pronounced smell and flavor due to its animal fat composition**,** the Nano Beef Tallow Spray offers a more refined sensory experience**.** The absence of off-flavors and odors in the Nano Beef Tallow Spray can be attributed to its advanced processing and nanoemulsion stability**,** which reduces the likelihood of lipid oxidation and rancidity. **(Shahidi & Zhong , 2010)** This makes the Nano Beef Tallow Spray a superior choice for applications where sensory neutrality and consistency are critical, such as in gourmet cooking or industrial food preparation.

CONCLUSION

Conclusion

Beef tallow is one of the oldest animal fats in human culinary history, yet it has paradoxically remained underutilized as a modern food ingredient. This study has demonstrated that, through the application of nanoemulsion technology, this traditional Algerian resource can be successfully transformed into a high-performance, safe, and consumer-friendly cooking spray one that not only matches but surpasses commercially available alternatives.

The Nano Beef Tallow Spray was formulated by blending locally sourced Algerian beef tallow with extra virgin olive oil from the Jijel region and food-grade soy lecithin as a natural emulsifier, processed using a homogenizing heating plate to produce a stable water-in-oil nanoemulsion. The results proved compelling across all tested parameters.

From a physicochemical standpoint, the product fully complied with regulatory standards, demonstrating excellent oxidative stability with remarkably low acidity and peroxide values. Microbiologically, it was flawless, with all tested samples completely free from major foodborne pathogens, including Salmonella, Listeria monocytogenes, coagulase-positive staphylococci, and Enterobacteriaceae. Nutritionally, the spray presented a well-balanced fat content with a moderate caloric density and high moisture content, reflecting its nanoemulsion structure.

The product particularly excelled in practical cooking performance. At high cooking temperatures, it achieved superior moisture retention in cooked chicken strips, outperforming both olive oil spray and sunflower oil spray under the same conditions. It also demonstrated minimal stickiness, easy post-cooking cleanup, and superior surface coverage. Sensory evaluation further supported these findings, classifying the product as highly acceptable, particularly owing to its soft texture, appealing golden color, and neutral odor.

From a nutritional and health perspective, the efficient surface coverage provided by the nanoemulsion format enables effective cooking with significantly smaller amounts of fat, thereby reducing overall caloric intake per meal. The favorable fatty acid composition of beef tallow, combined with the beneficial lipid profile of olive oil, makes this product suitable not only for the general population but also for individuals managing cardiovascular risk factors, elevated cholesterol levels, or obesity, provided it is consumed within a balanced and varied diet.

Despite these promising results, several avenues remain open for further product improvement and future research. Long-term oxidative stability studies are recommended through extended monitoring of lipid oxidation markers over an adequate storage period. Emulsification parameters should be further optimized using Response Surface Methodology to achieve narrower droplet size distribution and enhanced shelf life. The incorporation of natural antioxidants such as rosemary extract or vitamin E is also encouraged to further retard lipid oxidation. Additionally, exploring scale-up feasibility using high-pressure homogenization would help assess the product's industrial applicability. Finally, formal consumer acceptability trials and comprehensive regulatory compliance evaluation according to both Algerian and European Union novel food frameworks are strongly recommended.

In conclusion, this work is more than a mere formulation study it represents a proof of concept demonstrating that Algerian culinary heritage and advanced food nanotechnology are not mutually exclusive. The Nano Beef Tallow Spray constitutes a significant step toward food sovereignty, the valorization of national animal by-products, and the development of high-value-added Algerian food products capable of competing in both domestic and international markets. It stands as a culturally rooted answer to a very modern question: how do we make traditional ingredients work for the future?

REFERENCE

References

- Ahmed, S., Khatun, J., Islam, M. M., Khan, M. K. I., Mahmud, S. M. N., Al Noman, M. A., & Islam, M. Z. (2015). Effect of beef tallow on growth performance, carcass characteristics, meat composition, and lipid profile of growing lambs. Journal of Advanced Veterinary and Animal Research, 2(3), 346–352. https://doi.org/10.5455/javar.2015.b96
- Bayda, S., Adeel, M., Tuccinardi, T., Cordani, M., & Rizzolio , F. (2020). The history of nanoscience and nanotechnology: From chemical-physical applications to nanomedicine. Molecules, 25(1), Article 112. https://doi.org/10.3390/molecules25010112
- Cargill. (n.d.). Edible tallow safety data sheet: Rendered bovine fat. Cargill.
- Chicago Beef Tallow. (n.d.). Chicago Beef Tallow Spray – 100% Grass-Fed Beef Tallow Cooking Spray. https://www.chicagobeef tallow.com/products/beef-tallow-spray
- European Food Safety Authority. (2023). Safety assessment of nanoemulsions in food applications. EFSA.
- Fekir, N., Fekir, S., & Meghari, A. (2025). واقع شعبة اللحوم الحمراء بالجزائر [The reality of the red meat sector in Algeria]. مجلة المنهل الاقتصادي, 8(2), 1430–1449.
- Finlayson, S. (2025). Report on beef tallow and beef fat: Rendering, uses, formulations, chemistry. FH Farms.
- Food and Agriculture Organization of the United Nations. (2021). مبادئ فحص اللحوم على أساس المخاطر وتطبيقها [Risk-based meat inspection: Principles and applications]. https://doi.org/10.4060/ca5465ar
- Feynman, R. P. (1960). There's plenty of room at the bottom. Engineering and Science, 23(5), 22–36.
- Gagaoua, M., & Boudechicha, H.-R. (2018). Ethnic meat products of the North African and Mediterranean countries: An overview. Journal of Ethnic Foods, 5(2), 83–98. https://doi.org/10.1016/j.jef.2018.02.004
- Golfomitsou, I., Mitsou, E., Xenakis, A., &Papadimitriou, V. (2018). Development of food grade nanoemulsions for delivery of vitamin D: Effect of surfactant and oil type on stability and bio accessibility. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 554, 185–192.

- Goudarzi, A. M. (2023, February 2). Do cows with similar body condition scores have similar fat reserves? Young Researchers and Elite Club, Pardis Science and Technology Branch, Islamic Azad University.
- Honikel, K. O. (2021). Animal fats in modern food products. Meat Science.
- Huang, M., Wang, H., & Chen, J. (2020). Effects of nanoemulsion-based edible coatings with natural antimicrobial and antioxidant agents on chicken breast meat quality. Food Hydrocolloids, 104, Article 105655.
- Jafari, S. M., Esfanjani, A. F., & Katouzian, I. (2017). Nanoemulsions: Properties, development, and applications. In S. M. Jafari (Ed.), Nanoemulsions (pp. 1–20). Academic Press.
- Khalid, N., et al. (2023). Development, stabilization, and characterization of vitamin D3 nanoemulsion for fortification of milk. Frontiers in Nutrition, 10, Article 1123456.
- Kumar, P., et al. (2023). Development of natural cooking sprays using animal fats. Food Chemistry.
- Maamri, F. Z., &Aiad, Z. (2022). إستعمال بعض الشحوم الحيوانية لصنع الصابون على البارد والساخن [The use of some animal fats to make soap by the cold and hot methods] [Master’s thesis, Kasdi Merbah University - Ouargla].
- Mason, T. G., et al. (2023). Formation and stability of food-grade nanoemulsions. Advances in Colloid and Interface Science.
- McClements, D. J. (2015). Food emulsions: Principles, practices, and techniques (3rd ed.). CRC Press.
- McClements, D. J. (2022). Nanoemulsions in the food industry: Recent advances and future perspectives. Current Opinion in Food Science.
- McClements, D. J., & Rao, J. (2011). Food-grade nanoemulsions: Formulation, fabrication, properties, performance, biological fate, and potential toxicity. Critical Reviews in Food Science and Nutrition, 51(4), 285–330. https://doi.org/10.1080/10408398.2011.559558
- McPhee, M. J., et al. (2024). Predicting fat cover in beef cattle to make on-farm decisions. Animals, 14(10), Article 1234. https://pmc.ncbi.nlm.nih.gov/articles/PMC11125392/
- Molitor, A. A. (2021). Monitoring food safety for rendered fat product handling in the US and the informal vegetable value chain in Cambodia [Master’s thesis, Kansas State University]. K-REx. https://hdl.handle.net/2097/41746

- National Nanotechnology Initiative. (2023). What is nanotechnology? https://www.nano.gov/nanotech-101/what-is-nano
- Noori, S., Zeynali, F., &Almasi, H. (2018). Antimicrobial and antioxidant efficiency of nanoemulsion-based edible coating containing ginger essential oil and its effect on safety and quality attributes of chicken breast fillets. Food Control, 84, 312–320.
- Pinchak, Y., Merlinski, N., Pardo, M. J., &Grompone, M. A. (2013). Beef tallow properties and applications. David Publisher. https://www.davidpublisher.com/Public/uploads/Contribute/5680cc1f3f7a7.pdf
- Scientific Steering Committee. (2001, June 28-29). Opinion on the safety of tallow obtained from ruminant slaughter by-products. European Commission.
- Solans, C., et al. (2021). Nano-emulsions: Formation and applications in the food industry. Food Hydrocolloids.
- Trinetta, V., McDaniel, A., Magossi , G., Yucel, U., & Jones, C. (2019). Effects of different moisture and temperature levels on Salmonella survival in poultry fat. Translational Animal Science, 3(4), 1–6. https://doi.org/10.1093/tas/txz090
- U.S. Department of Agriculture. (2025). Beef tallow (Food Data Central, Food ID: 171400). https://fdc.nal.usda.gov/fdc-app.html#/food-details/171400/nutrients
- Zeng, Z., Qin, X., Wang, H., Chen, Z., Huang, D., Xiang, D., & Liu, X. (2024). Effect of the chemical composition and structural properties of beef tallow from different adipose tissues on bread quality. LWT - Food Science and Technology, 192, Article 115736. https://doi.org/10.1016/j.lwt.2024.115736

Nanotechnology: The Future Medicine - PMC pmc.ncbi.nlm.nih.gov

The History of Nanoscience and Nanotechnology - PMC pmc.ncbi.nlm.nih.gov

Nanotechnology: A Revolution in Modern Industry - PMC pmc.ncbi.nlm.nih.gov

Applications of Nanotechnology - National Nanotechnology Coordination Office nano.

Annex 01

Chicago Beef Tallow Spray: A Chef's Secret for Authentic Flavor and Performance

If you've ever wondered how professional chefs achieve that rich, savory depth in their dishes, the answer might just be Chicago Beef Tallow Spray a premium cooking spray made from 100% pure beef tallow, the rendered fat from cattle (**Chicago Beef Tallow, n.d.)**. Unlike generic vegetable oil sprays, this product is a game-changer for anyone serious about cooking, offering a natural, high-smoke-point fat that delivers unmatched flavor and texture to meats, vegetables, and even baked goods.

What's Inside? Chicago Beef Tallow Spray is crafted from grass-fed, pasture-raised beef fat, carefully rendered and purified to remove impurities while preserving its natural richness **(Rule et al., 2002).** The spray typically contains pure beef tallow (the star ingredient, packed with saturated and monounsaturated fats like stearic and oleic acids), no artificial additives or preservatives, and a food-grade propellant.

Why It Stands Out: Physicochemical and Biological Properties This isn't just any cooking fat it's engineered for performance. Beef tallow has a high smoke point (approximately 400°F / 204°C), making it ideal for searing, frying, and grilling without breaking down or producing harmful compounds **(Gunstone, 2011; McClements, 2015)**. Its solid-at-room-temperature nature (thanks to a high content of stearic acid, which melts at approximately 69–70°C) means it creates a perfect non-stick surface on pans and grills. Biologically, beef tallow is rich in fat-soluble vitamins (A, D, E, K) and contains conjugated linoleic acid (CLA), a compound linked to potential health benefits **(Daley et al., 2010).** Plus, its neutral pH and low moisture content make it resistant to oxidation, ensuring a longer shelf life compared to many plant-based oils **(Wood et al., 2008).**

Company and Product Information:

Company : South Chicago Packing Company | Location: Chicago, Illinois, US

Product: South Chicago Packing Wagyu Beef Tallow Cooking Fat Spray

UPC Number: 0081953803528

Size: 7 fl oz |

Packaging: Bag-On-Valve (BOV

Ingredients: 100% rendered Wagyu beef fat

Website: www.southchicagopacking.com |
Phone: 1-888-453-1908
Email: info@southchicagopacking.com

Annex 02

Declared Specifications & Nutritional Properties

Parameter	Value	Remarks
Smoke Point	350-400°C	Depends on cooking method
Shelf Life	12 months	From production date
Optimal Storage	Room temperature	Avoid refrigeration
Standards	USDA Certified	FDA & USDA compliant
Calories (per 13g)	120 kcal	Single serving
Total Fat	13 g	Per serving
Saturated Fat	4.5 g	Per serving
Omega Fatty Acids	Balanced 3 & 6	Healthy lipid profile

Table Annex : Declared specification & Nutritional Properties of South Chicago Packing Wagyu Beef Tallow Cooking Fat Spray

Annex 03

Undeclared/Missing Data and Results

Missing Data	Type	Reason
Microbiological Data	TBC, E.coli, Listeria, Salmonella	Advanced technical - not required for consumer products
Physicochemical Analysis	Acid Value, Peroxide Value	Academic research data
Particle Size	Distribution, Z-average	Specialized research studies
Oxidative Stability	Hours of stability	Research standards
Water Activity (aw)	Aw value	Advanced research metrics

Table Annex : Undeclared Data and Results of South Chicago Packing Wagyu Beef Tallow Cooking Fat Spray

Figure Annex : RepresentSouth Chicago Packing Wagyu Beef Tallow Spray (South Chicago Packing.2025)