THE POTENTIAL USE OF BEEF TALLOW FOR BIODIESEL PRODUCTION IN BRAZIL

O USO EM POTENCIAL DO SEBO BOVINO PARA A PRODUÇÃO DE BIODIESEL NO BRASIL

EL USO POTENCIAL DE SEMILLAS BOVINAS PARA LA PRODUCCIÓN DE BIODIESEL EN BRASIL

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Resumo

O biodiesel tem se apresentado mundialmente como uma alternativa viável aos combustíveis derivados do petróleo. Em 2018, as principais matérias-primas do setor brasileiro foram a soja (70,52%) e o sebo bovino (13,4%). A mistura obrigatória de biodiesel-diesel brasileira atualmente é de 10% (B10), mas B20 é estimado para 2030. Além disso, o Programa Nacional de Produção e Uso de Biodiesel (PNPB) pretende promover a diversificação de matérias-primas na matriz energética, onde o sebo bovino - resíduo da produção da carne bovina - vem ganhando importância. O Brasil se apresenta como o maior produtor e exportador comercial global de carne bovina. Assim, o uso do sebo bovino permitiria a expansão da produção de biodiesel sem competição combustível x alimento e proporcionaria um uso mais nobre do que o descarte para ele. Nesse sentido, este artigo analisa, por meio de uma revisão, o potencial do sebo bovino para a produção de biodiesel no Brasil. Essa matéria-prima possui preço, quantidade e qualidade para a geração de um biodiesel nas especificações exigidas pelos órgãos reguladores. Portanto, o sebo bovino é uma matéria-prima potencial para a expansão do setor de biodiesel no Brasil e essa experiência pode ser útil para outros países.

PALAVRAS CHAVE: Rede de carne. Sebo bovino. Biocombustível. Energia renovável. PNPB

Resumen

El biodiésel se ha presentado en todo el mundo como una alternativa viable a los combustibles derivados del petróleo. En 2018, las principales materias primas de este sector brasileño fueron la soja (70,52%) y el sebo bovino (13,4%). La mezcla brasileña obligatoria de biodiesel-diesel es actualmente del 10% (B10), pero se estima que B20 para 2030. Además, el Programa Nacional para la Producción y Uso de Biodiesel (PNPB) pretende promover la diversificación de materias primas en la matriz energética, donde el sebo de vacuno, un residuo de la producción de carne de vacuno, ha adquirido una importancia creciente. Brasil se presenta como el mayor productor y exportador comercial de carne vacuna del mundo. Entonces, el uso de sebo bovino permitiría la expansión de la producción de biodiesel sin competencia combustible x alimento y proporcionaría un uso más noble que su eliminación. En este sentido, este artículo analiza, a través de una revisión, el potencial del sebo bovino para la producción de biodiesel en Brasil. Esta materia prima tiene precio, cantidad y calidad para generar un biodiesel en las especificaciones requeridas por las agencias reguladoras. Por lo tanto, el sebo bovino es una materia prima potencial para la expansión del sector del biodiesel en Brasil y esta experiencia puede ser útil para otros países.PALABRAS CLAVE**:** Cadena de carne. Sebo bovino. Biocombustible. Energía renovable. PNPB

Abstract

Biodiesel has been presented worldwide as a viable alternative to petroleum-based fuels. In 2018, the main raw materials in this Brazilian sector were soybean (70.52%) and beef tallow (13.4%). The Brazilian mandatory biodiesel-diesel blend is currently 10% (B10), but B20 is estimated for 2030. Additionally, the National Program for the Production and Use of Biodiesel (PNPB) intends to promote the diversification of raw materials in the energy matrix, where the beef tallow - a residue of the beef production - has been increasing importance. Brazil presents as the global largest commercial beef producer and exporter. Then, the use of beef tallow would allow the expansion of biodiesel production without fuel x food competition and provide a nobler use than disposal for it. In this sense, this article analyzes, through a review, the potential of beef tallow for biodiesel production in Brazil. This raw material has price, quantity and quality for generating a biodiesel in the specifications required by regulatory agencies. Therefore, beef tallow is a potential raw material for the expansion of the biodiesel sector in Brazil and this experience can be useful for other countries.

KEYWORDS: Beef chain. Bovine tallow. Biofuel. Renewable energy. PNPB

1. Introduction

Faced with the demand for sustainability, renewable energy has gained relevance in recent decades, especially through the terms of replacing fossil fuels by biofuels.

Biodiesel - an alternative to current fossil fuels (YASIN et al., 2013; MONISHA et al., 2013) - emerges as a contributor to the reduction of greenhouse gas (GHG) emissions (ABBOUD et al., 2017), as it significantly reduces toxic emissions (ZHANG et al., 2017) and can be used on the diesel engine without any engine modification indicating that it has physical and chemical properties comparable to conventional diesel. Exhaust gases from biodiesel during combustion have less carbon monoxide, hydrocarbons, particles and sulfur dioxide compared to those from petrodiesel (NAUTIYAL et al., 2014).

Biodiesel is made from renewable resources; it has become attractive because of its environmental benefits (MA & HANNA, 1990). This is the logic behind European Renewable Energy Directives, which was an important driver responsible for expanding the European biodiesel market (IEA, 2011) In Brazil, National Program for the Production and Use of Biodiesel (PNPB) guided biodiesel production. Nowadays the PNPB, implemented commercially by Law Nº. 11,097/2005, requires the addition of 10% of biodiesel in commercialized diesel (B10). The Brazilian Energy Research Company (EPE) sets a scenario with a mandatory percentage of 20% by 2030 (UBRABIO, 2019).

Biodiesel is a synthetic diesel-like fuel derived from biomass such as vegetable oils or animal fats, and designated as B100 (MANIQUE et al., 2017). Due to the gradual increase in biodiesel production in Brazil and the use of soybean oil as a predominant raw material, the Brazilian government have pointed the need of include other inputs in this chain (ANP, 2019).

The waste tallow, such as chicken and mutton fats, is a low cost sustainable potential feedstock for biodiesel production (BHATTI et al., 2008). Among animal biomass, beef tallow stands out as the second most used raw material for the biodiesel production in Brazil. The beef production chain is one of the most important and organized Brazilian agribusiness chains, with high production scale, geographical coverage and low seasonality (CREMONEZ et al., 2015). In addition, the use of beef tallow for biodiesel production is another alternative for disposing of this animal waste, considered a potential polluter, not entering into the discussion about food X fuel (BANKOVIĆ-ILIĆ, 2014). Norway, for example, is in a good position for producing large amounts of biodiesel from residual animal fat (ANDERSEN & WEINBACH, 2010)

Brazil has the second largest cattle herd in the world, standing out as the largest exporter of beef in 2018 (ABIEC, 2019) With a beef production of 10.96 million tons in 2018 and a projected growth of 1.9% per year for the 2017/2018 to 2027/2028 period, it means a production of 12.146 million tons in 2028 (ABIEC, 2019). Thus, the national potential of biodiesel production from beef tallow may represent an activity of great interest to the meat and biodiesel plants industry, giving the possibility of using a byproduct instead of discarding it.

In this sense, this material aims to analyze, through a review, the potential of beef tallow for biodiesel production in Brazil, in order to explore scientific articles and data from regulators of the biodiesel sector and beef tallow production. The five sections are presented in this paper as follow: i) this introduction; ii) the technical features of the beef tallow and biodiesel production; iii) the PNPB and the scenario of biodiesel production in Brazil; iv) The Agro-industrial System (AGS) of biodiesel in Brazil and the potential to integrate the AGS of tallow into it; and, v) final considerations.

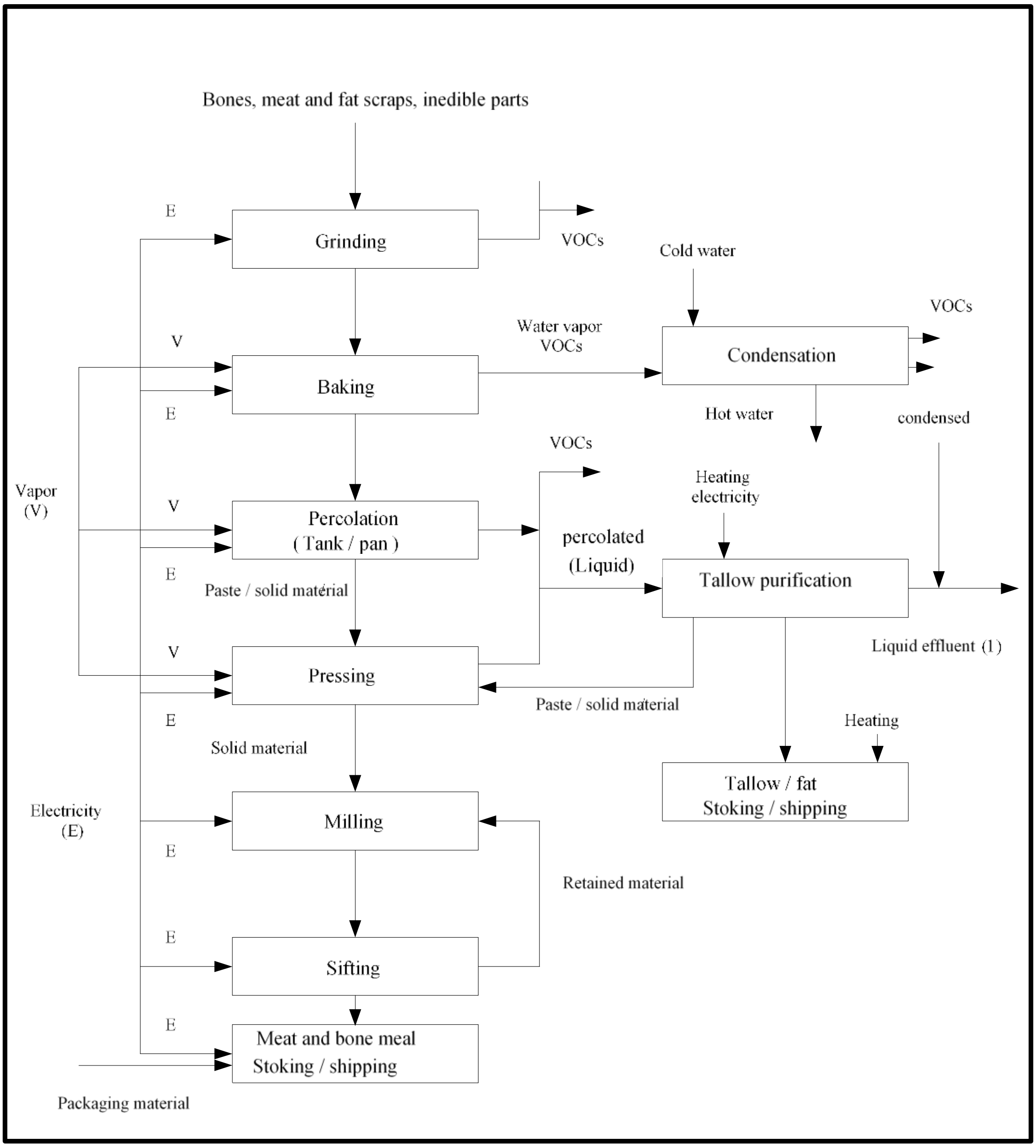
2. Technical features of beef tallow biodiesel

2.1. The beef tallow production process

Beef cattle generates several residues (such as bones, carcasses and fat) from the slaughter process, which are processed and converted to tallow. Slaughterhouses produce the raw material for the greases, following the steps: reception, corral, stunning and bleeding, skinning, evisceration, carcass cuts, refrigeration and boning (FREITAS, 2016).

The inedible material sent to the greases represents 38% of the live weight of a cattle. In the greases, the by-products and slaughterhouses waste are processed, such as blood, bones, hooves, horns, fat, meat trimmings, animals or their parts condemned by sanitary inspection and inedible viscera. Its main products are tallow, meat and bone meal (PACHECO & YAMANAKA, 2006).

Consequently, the use of bovine tallow for biodiesel production has gained special interest because it allows the use of discarded materials, allowing new jobs and minimizing the environmental impact. Bovine tallow for biodiesel production is, essentially, a waste product that has a higher annual production and greater economic viability than soybean oil and other vegetable oils (LIU et al., 2011). Figure 1 shows the general description of the main stages for producing tallow.



Note: VOCs = Volatile Organic Compounds, responsible for unpleasant smell.

Figure 1. Main stages of beef tallow and flour production. Adapted from (PACHECO & YAMANAKA, 2006).

The beef tallow can be stored or promptly enter in the process. In processing, the by-products are placed in the hopper and then transferred to a shredder where their size is reduced for baking. The bones and other parts are milled and grinded, generating a mass that follows by a screw conveyor to the cooking equipment. Cooking can be done by wet, dry or by drying in digesters (large amounts of raw materials), pots (smaller amounts) and autoclaves (cooking at higher pressures). After cooking, the equipment is opened and its contents is discharged into a steam-heated tank or percolator pan where the tallow is separated from solids by pressing, centrifuging or using organic solvents. The purification of the fatty waste from the slaughter is done through purification and refining (PACHECO & YAMANAKA, 2006).

After percolation, the tallow is sent to a decanter tank for storage and eventual final separation of the aqueous phase. In the purification, water and impurities from the material used for the tallow production are eliminated. The solid material removed from the tallow in this operation is added to the percolation solids. From the decanter tank, the tallow is removed and used to make biodiesel, soap and other products. The solid material is hot pressed, ground and sieved, to adjust the grain size of the flour. The material retained returns to the mill. Going through the sifting, the meat/bone meal is bagged. After this process, tallow and flour are destined for stock or shipping (PACHECO & YAMANAKA, 2006).

The tallow separated during the cooking is accumulated in a serpentine-heated reservoir in order to be used later for biodiesel production (ARAÚJO et al., 2010; LEVY, 2011; PIASZYK, 2012; BUENO, FREITAS & NACHILUK, 2012).

2.2. Biodiesel technical descriptions

Vegetable oils or animal fats are esters of saturated and unsaturated monocarboxylic acids with the trihydric alcohol glyceride, called triglycerides. Biodiesel is produced by a chemical reaction of a triglyceride and an alcohol in the presence of a catalyst, it is known as transesterification reaction. Methanol is preferred alcohol because of its low cost (Equation 1) (LEUNG, WU & LEUNG, 2010; SHAN et al., 2018). The use of ultrasonic irradiation may be a promising alternative method, decreasing the reaction time (TEIXEIRA et al., 2009).

$$
\begin{array}{lcccccl}
CH_2\text{-}O\text{-}CO\text{-}R_1 & & & & CH_2\text{-}OH & & R\text{-}O\text{-}CO\text{-}R_1 \\
| & & & & | & & \\
CH_2\text{-}O\text{-}CO\text{-}R_2 & + & 3ROH & \xrightarrow{\text{Catalyst}} & CH\text{-}OH & + & R\text{-}O\text{-}CO\text{-}R_2 \qquad (1) \\
| & & & & | & & \\
CH_2\text{-}O\text{-}CO\text{-}R_3 & & & & CH_2\text{-}OH & & R\text{-}O\text{-}CO\text{-}R_3 \\
\text{(triglyceride)} & & \text{(alcohol)} & & \text{(glycerol)} & & \text{(mixture of fatty acid esters)}
\end{array}
$$

(R_1, R_2, R_3 are long-chain hydrocarbons, sometimes called fatty acid chains)

Vegetable oils and fats may contain small amounts of water and free fatty acids (FFA). The alkali catalyst will react with the FFA, forming soap and water, it is known as saponification reaction (Equation 2). This reaction is undesirable, the soap decreases the biodiesel yield, inhibits the esters separation from glycerol, binds with the catalyst (more catalyst will be needed) and increasing the process cost. The water can react with the triglycerides forming diglycerides and FAA, it is known as hydrolysis reaction (Equation 3). This reaction is also undesirable, it retards the transesterification (LEUNG, WU & LEUNG, 2010).

$$\underset{\text{(FAA)}}{R_1\text{-}COOH} + \underset{\text{(sodium hydroxide)}}{NaOH} \longrightarrow \underset{\text{(soap)}}{R_1COONa} + \underset{\text{(water)}}{H_2O} \qquad (2)$$

$$\begin{array}{l} CH_2\text{-}O\text{-}CO\text{-}R_1 \\ | \\ CH_2\text{-}O\text{-}CO\text{-}R_2 \\ | \\ CH_2\text{-}O\text{-}CO\text{-}R_3 \\ \text{(triglyceride)} \end{array} + \underset{\text{(water)}}{H_2O} \longrightarrow \begin{array}{l} CH_2\text{-}OH \\ | \\ CH\text{-}O\text{-}CO\text{-}R_2 \\ | \\ CH_2\text{-}O\text{-}CO\text{-}R_3 \\ \text{(diglyceride)} \end{array} + \underset{\text{(FAA)}}{R_1\text{-}COOH} \qquad (3)$$

The transesterification reaction can be done using several types of catalysts: i) alkali homogeneous (NaOH, KOH) have high catalytic activity and low cost (SHAN et al., 2018; REMÓN et al., 2017; ABDULLAH, 2017); ii) heterogeneous catalysts (metal oxides, zeolites, hydrotalcites) are recyclable and eco-friendly (LU et al, 2015; ALISMAEEL, 2018; CORAL et al., 2019; SILVEIRA et al., 2019) and, iii) enzymes catalysts (lipase) avoid the undesirable soap formation (HAAS, 2005; GULDHE et al., 2015 ; ADEWALE, VITHANAGE & CHRISTOPHER, 2017).

Therefore, biodiesel is a synthetic diesel-like fuel composed of long chain monoalkyl esters of fatty acids derived from vegetable and animal oils. This biofuel has a renewable and eco-friendly nature; it is introduced in the national market with a unique specification, focusing on quality assurance, consumer rights and the environmental preservation (CAIXETA, 2009; SINGH et al., 2020).

The Resolution ANP (National Agency of Petroleum, Natural Gas and Biofuels) Nº 45/2014 guides the specifications for biodiesel sale in Brazil (ANP, 2014). Independent of the raw material and the technological route, the final product must necessarily meet the specifications (GUTIÉRREZ-OPPE, 2013; GOULART & COTI-ZELATI, 2016). Chart 1 lists the general properties of biodiesel.

Chart 1. General Properties of Biodiesel

Chemical name	**Fatty acid methyl ester**
Chemical Formula Range	**Methyl estersC_{14}-C_{24} or $C_{15\text{-}25}$ $H_{28\text{-}48}O_2$**
Kinematic viscosity scale	**3,3-5,2 mm^2/s, at 40 °C**
Density range	**860-894 kg / m^3, at 15 °C**
Boiling point	**200º C**
Flash point range	**155-180º C**
Distillation scale	**195-325º C**
Steam pressure	**< 5 mm Hg, a 22° C**
Solubility in water	**Insoluble in water, but can absorb up to 1500 ppm of water**
Physical appearance	**Light yellow to dark yellow and clear liquid**
Smell	**Soap smell**
Biodegradability	**More biodegradable than petrodiesel**
Reactivity	**Stable but reacts with strong oxidizers**

Source: Demirbas (2011).

The biodiesel quality directly depends on the control of some factors such as the amount of glycerol, water and sediment, as well as long-term storage stability. Suspended water poses a problem for fuel injection systems and sediments may correspond to suspended materials that may cause filter clogging (KNOTHE, 2006).

High percentage monounsaturated fatty acids are a requirement for choosing the best feedstock for biodiesel production. Variations in biodiesel energy density are more dependent on the raw materials used than the production process (ARANSIOLA et al., 2014). However, not only the raw material, but also the technological processes can generate great influence on the large-scale production of biodiesel in a plant (FERNANDEZ, LIU & ZHAO, 2017).

2.3. Beef tallow biodiesel technical descriptions

The beef tallow consists of triglycerides. In order to have favorable application conditions in the production of biodiesel, it is necessary to neutralize and dehumidify, making the humidity and acidity at a lower level. Most processes establish 0.2% of acidity and 0.1% of maximum humidity. Neutralization can be carried out with alkaline sodium or potassium hydroxide solution, free fatty acid saponification occurs, forming a separate sludge through decantation. The product is washed with brine and dehumidification is performed through the drying process (BARROS & JARDINI, 2017).

A feature of most oils is a profile composed of five fatty acids: palmitic, stearic, oleic, linoleic and linolenic (KNOTHE & RAZON, 2017). Table 1 presents the chemical composition of some raw materials for biodiesel production.

Table 1. Chemical composition of the main raw materials used in biodiesel production

Fat	**Fatty acids (%)**						
	Fatty acids (%)	**Fatty acids (%)**	**Fatty acids (%)**	**Fatty acids (%)**	**Fatty acids (%)**	**Fatty acids (%)**	**Fatty acids (%)**
Beef tallow	3	27	11	7	48	2	2
Pig lard	---	24.6	---	15	50.4	10	---
Soy	0.2	11	0.2	2	20	64	9.5
Frying oil	0.2	8.0	4.4	4.6	48.4	32.0	2.4

Source: Ramos et al. (2017); Camargo (2016); Piaszyk (2012); Banković-Ilić et al. (2014)

Saturated compounds (myristic and palmitic) have higher cetane numbers and are less susceptible to oxidation. Thus, the higher myristic and palmitic acid content gives to the beef tallow the properties of high melting point and high viscosity (BANKOVIĆ-ILIĆ et al., 2014). Biodiesel esters determine many properties that depend on the composition of the raw material used for their production, which influence fuel characteristics, such as degree of unsaturation, chain length, and stream branching (RAMÍREZ-VERDUZCO, RODRÍGUEZ-RODRÍGUEZ & JARAMILLO-JACOB, 2012). Table 2 lists the physicochemical properties of beef tallow and biodiesel produced from beef tallow.

Table 2. Physicochemical properties of beef tallow and beef tallow biodiesel

Parameter	Standard	Beef tallow	Beef tallow biodiesel	Specification
Viscosity (mm^2/s)	ASTM D 455	5.67	4.9	3.0-6.0
Superficial tension (mN/m)	-	16.1	15.6	-
Specific weight at 20ºC (kg/m^3)	ASTM D 4052	875.7	870.3	850-900
Flash point (ºC)	ASTM D 93	297.0	187.0	>100
Combustion point (ºC)	-	303.0	191.0	-
Acidity level (mg KOH/g)	EN14104	3.30	0.065	0.5
Free fatty acids (%)	-	0.85	-	-
Saponification Index (mgKOH/g)	-	246.1	241.01	-
Iodine Index (g of iodine/100g)	EN14214	44.2	40.2	< 120 g of iodine/100g
Total sulfur (% wt)	ASTM D 5453	0.9	1.4	50
Moisture content (%)	-	0,760	-	-
Water and sediment (%)	ASTM D 6304	0,5	0,0	500

Source: Moraes (2008); Silva et al. (2014)

The Brazilian biodiesel specifications (ANP 42/2004) are closer to the European and American ones (DIN 51606 and ASTM D 6751-02) (LA ROVERE, PEREIRA & SIMÕES, 2011). The structural characteristics of biodiesel such as degree of unsaturation, chain length and chain branching influence its physical properties. The chemical composition that makes the features of biodiesel fuel includes cloud point, cetane number, density, viscosity filter fill point, oxidative stability, iodine value, peroxide value, of inflammation and lubricity (SUNDUS, FAZAL & MASJUKI, 2017).

Higher stearic and palmitic acid contents give to beef tallow the unique properties of high melting point and high viscosity. The composition and properties of the raw material used for biodiesel production have an influence on fuel characteristics. The high cloud point of methyl esters from animal fat is indicative of a high concentration of saturated fatty esters. Biodiesel solidifies at low temperatures, which can clog the filters or even become so thick that it cannot be pumped from the fuel tank to the engine (TEIXEIRA et al., 2010).

3. The biodiesel production in Brazil

There is a strong presence of the government in the Brazilian biodiesel production. The PNPB was commercially implemented in 2005, its legal guidelines seek to promote a diversified base of raw materials, family farmers' social inclusion policies, ensuring supply and reducing greenhouse gas emissions (Chart 2).

Chart 2. Main legal determinations about Brazilian biodiesel production

Standard	Content
DSN 02/07/2003	It establishes the interministerial working group responsible for the studies about the feasibility of using biodiesel as an alternative energy source, proposing, if necessary, the necessary actions for the use of biodiesel.
DSN 23/12/2003	It establishes the interministerial executive commission responsible for the implementation of actions for the production and use of biodiesel as an alternative energy source.
Resolution ANP 42 24/11/2004	It establishes the specification for the commercialization of biodiesel that can be added to the diesel oil in the proportion of 2% by volume.
Decree 5.297 06/12/2004	Provides for the reduction coefficients of the contribution rates to PIS / PASEP and COFINS levied on the production and sale of biodiesel, the terms and conditions for the use of differentiated rates.
Law Nº 11.097 13/01/2005	Provides the introduction of biodiesel in the Brazilian energy matrix.
Law Nº 11.116 18/05/2005	Provides the Special Registration, at the Federal Revenue Secretariat of the Finance Ministry, of a biodiesel producer or importer and the incidence of the PIS / PASEP and COFINS Contribution on

	revenues from the sale of this product.
Decree 5.448 20/05/2005	Regulates the paragraph 1, Article 2nd of Law Nº 11,097, January 13th, 2005, which provides the introduction of biodiesel in the Brazilian energy matrix.
Resolution CNPE 03 23/09/2005	It promotes the rational use of the country's energy resources and establishes guidelines for specific programs such as biofuels.
Ordinance MME 483 03/10/2005	It establishes the guidelines for Biodiesel acquisition auctions by ANP.
IN MDA Nº 02 30/09/2005	It establishes the criteria and procedures related to the framing of biodiesel production projects to SCS.
Resolution CNPE 05 03/10/2007	It establishes as its initial milestone January 1st, 2008, to meet the minimum mandatory intermediate percentage of 2%, by volume, of the addition of biodiesel to diesel fuel sold to the final consume.
Resolution CNPE 02 13/03/2008	It establishes at 3%, by volume, the minimum mandatory percentage of addition of biodiesel to diesel sold to the final consumer, from July 1st, 2008.
Decree 6.458 14/05/2008	It expands the family farming raw material options for the North, Northeast and Semi-arid regions and changes the PIS / CONFINS for these regions.
Resolution CNPE 02 27/04/09	It establishes in 4%, by volume, the minimum mandatory percentage of biodiesel addition to diesel sold to the final consumer, from July 1, 2009.
Resolution CNPE 06 16/09/2009	It establishes at 5%, by volume, the minimum mandatory percentage of addition of biodiesel to diesel sold to the final consumer, from January 1st, 2010.
Law Nº 12.490 16/09/2011	Gives new treatment to biofuels in Brazil. Establishes principles and objectives for the

	National Energy Policy.
Decree 7.768 27/06/2012	Changes the Decree No. 5,297, of December 6th, 2004, about the coefficients for reducing the contribution rates to PIS / PASEP and COFINS on the production and sale of biodiesel, and the terms and conditions for use of different tax rates.
Ordinance MME 476 15/8/2012	Provides for the guidelines that must be observed by the ANP when conducting Public Auctions intended for the contracting of biodiesel necessary to meet the minimum mandatory percentage referred to in Law No. 11.097/ 2005.
Ordinance 60 06/09/2012	Provides the criteria and procedures related to the grant, maintenance and use of Social Fuel Seal.
MP Nº 647 28/05/2014	It establishes, by volume, the mandatory minimum percentage of biodiesel added to diesel sold to the final consumer from: I. July 1st, 2014 – 6% / II. November 1st, 2014 – 7%.
Resolution CNPE 03 21/09/2015	It authorizes the commercialization and voluntary use of biodiesel blends in excess of the percentage of their mandatory addition to diesel oil, subject to the maximum limits for the addition of biodiesel to diesel oil, by volume: I. 20% in captive fleets or road consumers served by point of supply; II. 30% in rail transport; III. 30% in agricultural and industrial use; and IV. 100% for experimental use, specific or other applications.
Law Nº 13.263 23/03/2016	It establishes, by volume, the mandatory minimum percentage of biodiesel added to diesel sold to the final consumer from: I. March 1st, 2017 – 8% / II. March 1st, 2018 – 9%. III. March 1st, 2019 – 10%.
Ordinance MME 116 04/04/2013	Establishes specific guidelines for biodiesel stocks in the country.
Resolution ANP 45 25/08/2014	It establishes the specification of biodiesel and the quality control obligations to be met by the several economic agents that commercialize the product throughout the national territory.

Law No. 13.033 24/09/2014	Provides the mandatory addition of biodiesel to diesel oil sold to the final consumer.
Law 13.263 23/03/201.6	Changes the Law N^{o} 13.033 / 2014, provides the addition percentages of biodiesel to diesel oil sold in the national territory.
Resolution CNPE 23 09/11/2017	Establishes the mandatory addition, by volume, of 10% of biodiesel to diesel sold to the final consumer, from March 1st, 2018.

Source: Brasil (2003 a,b); Brasil (2004a,b,c); Brasil (2005); Brasil (2005a,b,c,d,e); Brasil (2006); Brasil (2008a,b); Brasil (2009); Brasil (2012a,b); Brasil (2014); Brasil (2015a,b); MME(2016, 2017)

The Social Fuel Seal (SFS) is related to the implementation of the PNPB social guidelines. It is a certification for biodiesel plants that include family farmers as suppliers of raw materials for biodiesel production, according to the potential of each Brazilian region. As a governmental incentive, the biodiesel plants receive tax advantages and guarantee to sale the biodiesel at auctions promoted by the government (MAPA, 2019)

From September 2015, the acquisition of beef tallow has been included by the Ministry of Agrarian Development (MDA) to the SFS through Ordinance Nº 337, reporting these criteria (Chart 3) for the inclusion process (MDA, 2015).

Chart 3. Criteria for SCS in biodiesel production.

Minimum purchase percentage from family farming	- 15% to the North and Midwest region;
	- 30% to the Southeast, Northeast and Semiarid regions;
	- 40% to the Southern region.
Raw material from agricultural cooperatives	The cooperative must be enabled in accordance with regulations issued by the MDA. The amount of raw material traded must come exclusively from the cooperative members holding the Pronaf Declaration of Aptitude (DAP) registered in the database of the Secretariat of Family Farming (SAF).
Agreement	The biodiesel producer must enter into prior contracts with all family farmers and/or agricultural cooperatives. In the case of cattle, the agreement must be signed respecting the minimum term of 180 days prior to marketing, duly evidenced by invoice.
Provision of technical	The biodiesel producer should ensure technical assistance and training for the production of raw materials - developed directly by the biodiesel producer's

assistance services and training to family farmers	technical team or by institutions / cooperatives / companies hired or contracted by it - to all hired family farmers.	
	In planning and implementing technical assistance and training, it is recommended the attention to the principles and targets of the National Policy on Technical Assistance and Rural Extension for Family Farming and Agrarian Reform (PNATER).	
	Technical assistance for the production of animal origin raw materials, under the responsibility of the biodiesel producer should be implemented at the following stages:	a) decision making and planning about animal production; b) preparation and / or follow-up of the technical project for animal production, in the case of claims for agricultural financing of production or advance of inputs made by the biodiesel producer; c) management of animal production; d) slaughter, when applicable; and e) payment of financing, when applicable.
Documentation	The biodiesel producer will keep a record, with supporting documentation of the raw material purchases made each calendar year for a period of 05 (five) years, without prejudice to the deadlines set by law.	a) The documentation of the acquisition will be provided as current state legislation. b) The documentation of the value of the raw material purchases shall contain, in the field of supplementary information, the farmer's DAP number or, when applicable, the authorized agricultural cooperative. c) In the case of animal production, the biodiesel producer must also present the Animal Transport Guide (GTA).
Reporting to MDA	i – every year, until the 15th day of the month immediately following the end of the calendar year for the criteria of acquisitions and agreement with family farming; and ii –every year, until the last business day of the month immediately following the end of the calendar year for cases of assistance information and technical training of family farmers, input donations and support for agricultural research.	

Source: Elaborated from (BRASIL, 2014c).

The regulation of the use of animal fats occurred through Ordinance Nº 515/2018, which defines the same criteria for concession and use of SCS in the acquisition of raw materials of plant or animal origin (BRASIL, 2018b). It is noteworthy that the PNPB started to consider bovine tallow as part of SCS, because it understands cattle ranching as an activity practiced by small and medium rural owners (SILVA et al., 2015).

Allied to the SCS, another important PNPB regulation was the deadlines and the minimum mandatory percentage of biodiesel added to diesel (Bx) sold to the final consumer in any part of the Brazilian territory. The regulation allowed the voluntary addition of 2% biodiesel to diesel (B2) in 2005 and the mandatory addition in 2008, gradually increasing over the years. In 2010, the blend moved to

B5, projecting the country among the largest biodiesel producers worldwide. The B6 was instituted in 2014, and since November of the same year the B7 became effective. In 2016, mixtures B8, B9 and B10 were enacted to be affected respectively in 2017, 2018 and 2019, as well as B15 and B20 in 2025 and 2030 respectively (BRASIL, 2005; MME, 2018; UBRABIO, 2019). Figure 2 shows the projections of biodiesel demand over the ten-year horizon (2017-2027).

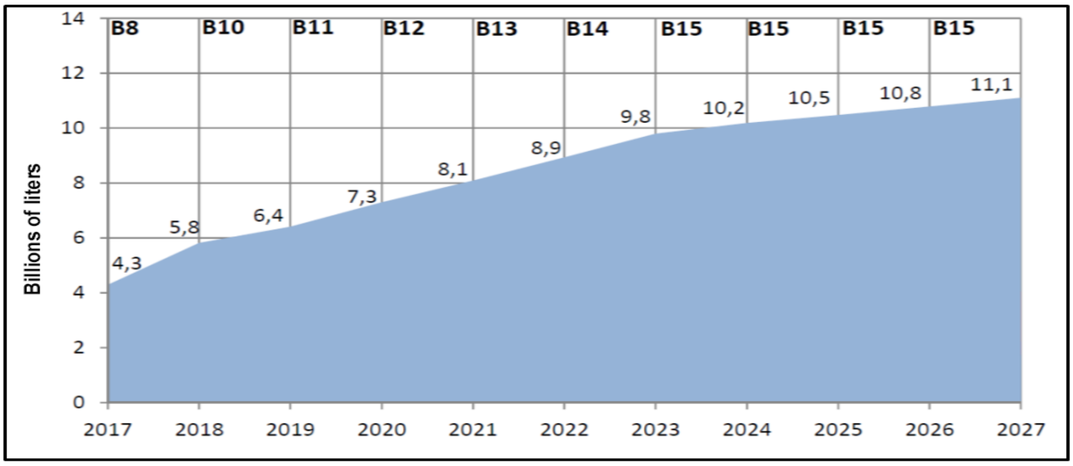


Figure 2. Biodiesel demand from 2017 until 2027 (BRASIL, 2018c).

The diversity of feedstock suitable for biodiesel production is classified in four categories: i) oils and fats of animal origin; ii) oils and fats of vegetable origin; iii) waste frying oils; and iv) fatty wastewater materials. Any substance containing triglycerides in its composition may be used for the production of biodiesel, as shown in Chart 4.

Chart 4. Raw materials for biodiesel production, origin and production.

Category	**Origin**	**Obtaining**
Animal oils and fats	Slaughterhouses, producers and tanneries	Extraction with water and steam
Vegetable oils and fats	Temporary and permanent agriculture	Mechanical extraction by solvent or mixed
Frying waste oils	Commercial and industrial cooking	Accumulations and collections
Sewage greases	City and industrial wastewater	Process still under investigation.

Source: Brasil (2003b)

Since 2010, the main raw material used for biodiesel production in Brazil has been the soybean oil, followed by the beef tallow (Table 3).

Table 3. Percentage of raw material consumption in biodiesel production in Brazil from 2010-2018.

Type of raw materials	2010	2011	2012	2013	2014	2015	2016	2017	2018
Soybean oil	82.03	72.98	70.54	68.13	73.09	82.43	69.30	69.92	70.00
Beef tallow	13.43	16.43	19.57	27.13	21.94	16.01	16.94	13.64	13.24
Cotton oil	2.42	5.52	5.68	1.56	2.84	0.16	1.74	0.29	0.86
Palm oil	0.20	0.41	0.22	0.0	0.0	0.09	0.55	0.88	1.33
Used fry oil	0.20	0.20	0.99	0.96	0.74	0.12	0.98	1.35	1.65
Swine fat	0.57	0.30	0.55	0.60	0.30	0.53	1.51	2.26	2.14
Chicken fat	0.08	0.02	0.16	0.0	0.05	0.05	0.28	1.06	0.85
Other fats	1.07	4.14	2.27	1.61	0.98	0.61	8.10	10.40	9.74

Source: ANP (2016, 2017, 2018)

Beef tallow, the second most widely used raw material, is expected to maintain a prominent position over the ten-year horizon (BRASIL, 2018c). Over the years, the peak use of beef tallow occurs simultaneously with the low use of soybean, which reflects its importance as a complementary raw material for biodiesel production, especially in the off-season soybean (Figure 3).

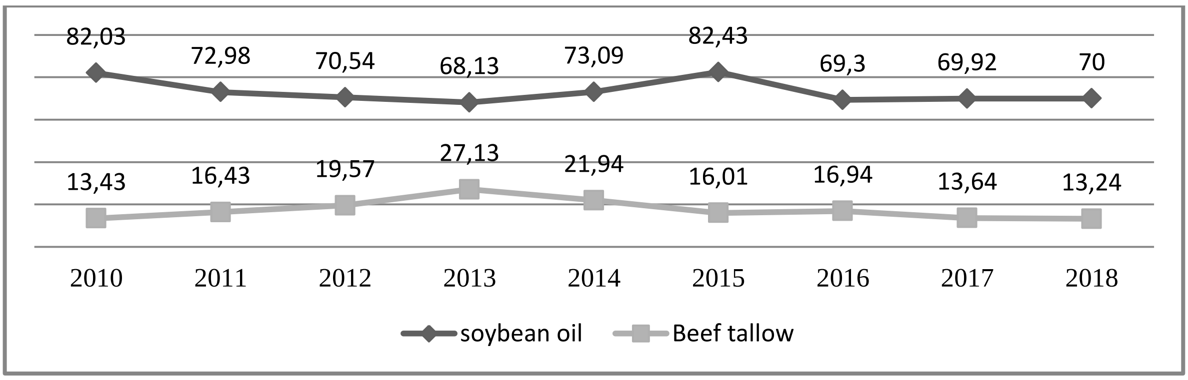


Figure 3. Soybean and beef tallow participation in biodiesel production in Brazil (ANP, 2018).

It is observed that the percentage of beef tallow participation increased gradually from 2010 to 2014, however, from 2015 it has been falling gradually. The role of commodities in the Brazilian biodiesel market considers as essential a standardized raw material, with abundant supply, which does not vary significantly in terms of its quality (ALVES, BELARMINI & PÁDULA, 2017). Thus, the complexity and breadth of this commodity market limits the diversification of oilseeds for biodiesel production. The production scale, product convertibility options and the way of the soy complex is structured make the soybean biodiesel one of the most economically viable alternatives for Brazil (CÉSAR et al., 2019). The social projects developed with soy are also more competitive (RIBEIRO et al., 2018) than other raw materials as there is a greater organization by farmers, which facilitates the governance of the productive chains.

However, by 2030, there will be changes in this scenario through public policies aimed to incentive the beef production chain, including the intensification of pasture production and utilization, the opening of new export markets and consequently increasing the domestic production of bovine tallow. Cattle slaughter in Brazil is estimated to reach 63 million heads by 2030, generating nearly 1.5 million tons of tallow (23 kg on average per head), with 1.3 million going to biodiesel production. It is also possible to recover tallow from butcher's carcasses, which raises the potential to 34 kg per head, and generates an additional 400,000 tons/ year in tallow, what can be entirely used for the production of biodiesel. However, the last use still requires changes in Brazilian legislation (ABIOVE, 2016; PÁDULA et al., 2012)

In Brazil, the percentage of feedstock used for biodiesel production changes among regions. In 2018, bovine tallow was the most widely used raw material in the Southeast and the second most used raw material in the North, Northeast and South. In the Midwest Region, beef tallow was the third raw material (Table 4).

Table 4. Raw materials used in biodiesel production in several Brazilian regions in 2018.

Raw material description	North	Northeast	Midwest	Southeast	South
Soybean oil	58.45%	39.71%	78.89%	23.89%	75.76%
Beef tallow	37.43%	24.45%	5.96%	33.78%	13.99%
Cotton oil	0.40%	4.46%	0.88%	0.80%	0.26%
Other Fat materials	1.76%	15.89%	12.59%	10.04%	5.92%
Used frying oil	0.00%	0.15%	0.65%	15.26%	0.33%
Pork fat	0.00%	0.00%	0.28%	10.81%	2.73%
Chicken fat	0.00%	0.01%	0.11%	4.83%	0.84%
Palm oil	1.97%	15.33%	0.42%	0.47%	0.00%
Corn oil	0.00%	0.00%	0.23%	0.09%	0.00%
Colza oil	0.00%	0.00%	0.00%	0.00%	0.18%
Glycerin	0.00%	0.00%	0.00%	0.02%	0.00%

Source: Elaborate from (ANP, 2019)

Thus, bovine tallow, plentiful throughout the country, presents itself as an opportunity for diversification of raw material, with economic advantages, as it is closer to biodiesel plants outside the

Center-South regions. It also presents a favorable price in relation to oilseeds and favorable production properties.

4. The biodiesel agro-industrial system and the potential for use of beef tallow

The agro-industrial system (AS) is the set of participants involved in the production, processing and distribution of a specific product, including supply, operations and consumption, as well as institutions that affect and coordinate the product flow, such as government, associations and markets (ZYLBERSZTAJN, 2005).

The Brazilian Biodiesel AS is composed of three basic and integrated processes: (1) supply; (2) production; and (3) distribution (Figure 4). These processes provide the basic framework for converting raw materials into biodiesel and distributing the final product

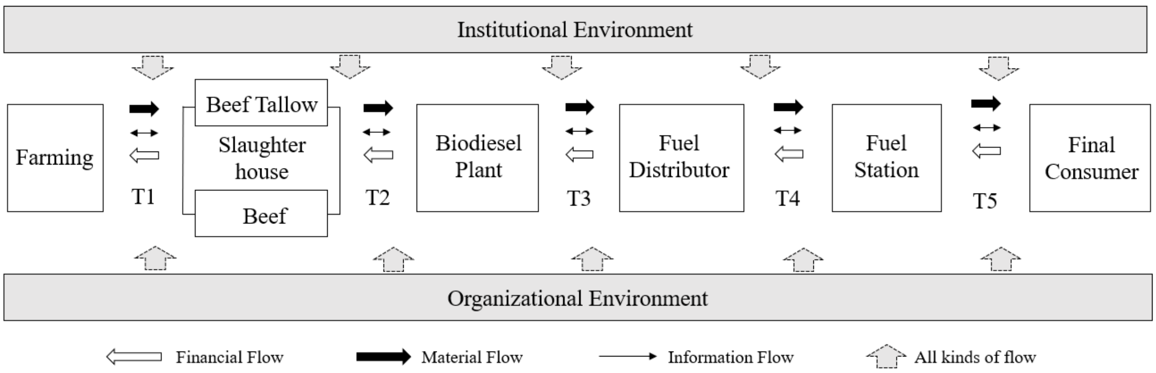
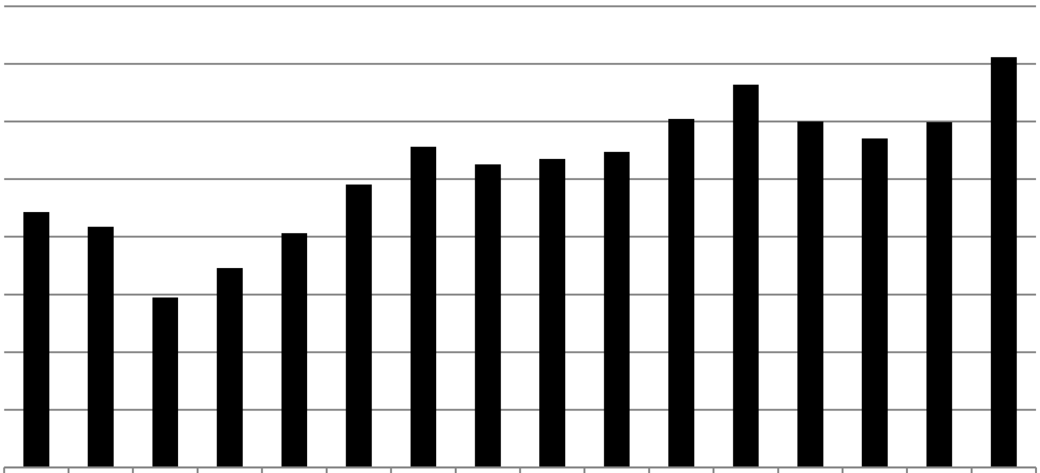


Figure 4. Brazilian Biodiesel Agro-industrial System. Adapted from (CASTRO & LIMA, 2003).

According to the Brazilian Confederation of Agriculture and Livestock, the national herd grew 3.3% in 2018, reaching 213 million heads. Historical information - in the period 2005-2018 - and livestock projections until 2028 is represented in Figure 5.



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2023	2028
■ Heads	207.157	205.886	199.752	202.307	205.308	209.541	212.815	211.279	211.764	212.366	215.221	218.191	215.004	213.523	214.947	220.567

Figure 5. Evolution of the Brazilian cattle (thousand heads). Elaborated from (ABIEC, 2019; IBGE, 2019a).

Cattle are slaughtered in slaughterhouses to obtain meat and meat products for human consumption. As a consequence of slaughter operations, beef tallow originates as a byproduct (PACHECO & YAMANAKA, 2006). In 2018, 32.043 million heads of cattle were slaughtered, an increase of 3.8% over the previous year. “This was the second consecutive increase in the historical annual series of cattle slaughter after the falls between 2014 and 2016” (IBGE, 2018).

Grease is responsible for turning slaughterhouse waste into by-products used in various other processes. According to the Brazilian Recycling Association, 12.5 million tons of animal slaughter waste is generated annually. In cattle slaughter, approximately 38% of the weight is destined for recycling. Due to the increase in cattle slaughter volume in the country, there was an increase in beef tallow production (ABRA, 2018). Figure 6 represents the correlation between cattle slaughter and an estimate for Brazilian tallow production from 2005 to 2018.

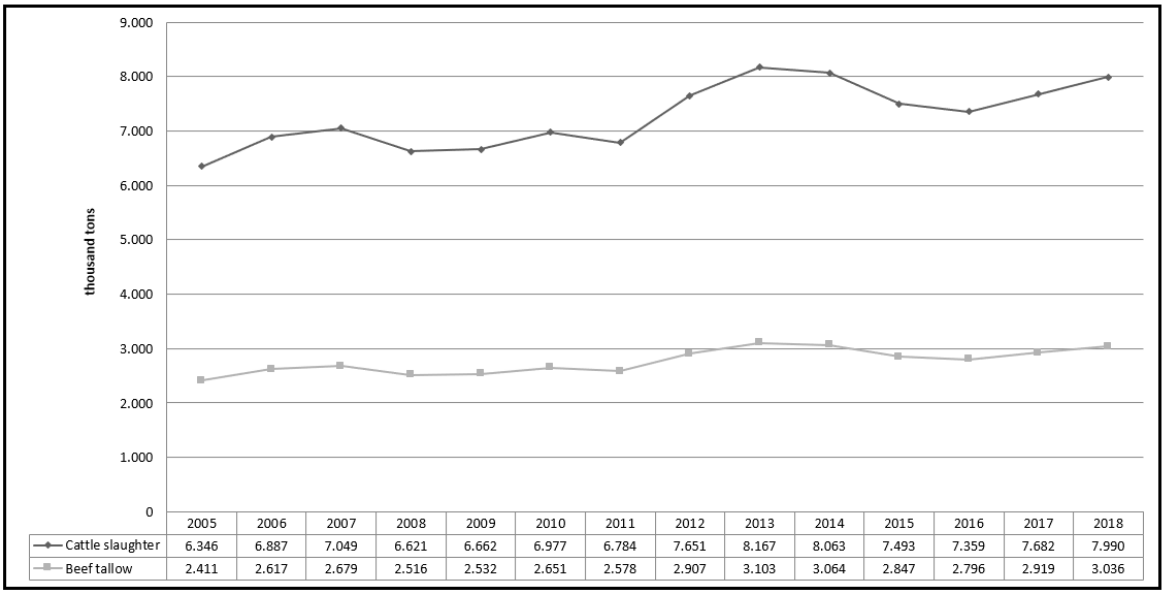


Figure 6. Annual evolution of cattle slaughter x Estimated Brazilian production of beef tallow – Brazil – 2005-2018 (in thousands of tons). Elaborated from (IBGE, 2019b).

So far, due to PNPB, Brazil had a cumulative production of 34.8 million m^3 of biodiesel. In 2018, biodiesel production reached 5.3 million m^3, an increase of 24.67% over 2017 (ANP, 2019). Regarding the share of biodiesel production from the use of beef tallow beef tallow, in 2018, it was around 13.24% when compared to other raw materials, presenting an increase around 21% compared to 2017 (ANP, 2018) (Table 5).

Table 5. Evolution of beef tallow biodiesel production in Brazil (2008-2018).

Year	Biodiesel production (m^3)	Beef tallow participation (%)	Beef tallow participation (m^3)	Variation (%)
2008	1,167,128.0	13.40%	156,395.0	-
2009	1,608,448.0	19.43%	312,521.0	99.83%
2010	2,386,438.0	13.43%	320,499.0	2.55%
2011	2,672,760.0	16.43%	439,134.0	37.02%
2012	2,717,483.0	19.57%	531,811.0	21.10%
2013	2,917,495.0	27.13%	791,516.0	48.83%

2014	3,419,838.0	21.94%	750,312.0	-5.21%
2015	3,930,503.0	16.01%	629,274.0	-16.13%
2016	3,810,952.0	16.94%	645,575.0	2.59%
2017	4,291,294.0	13.64%	585,333.0	-9.33%
2018	5,337,135.0	13.24%	706,637.0	20.72%

Source: Elaborate from (ANP, 2018)

It is noteworthy that, another niche market that may be an inducer of the use of biodiesel is the supply of isolated power generation units in the North of the country, where the locally produced fuel, with raw material from the region, may have more attractive prices because it does not require special logistics for remote delivery (ANP, 2018).

The context discussed presents the beef tallow as a viable raw material for biodiesel production, which also includes the possibility of expanding its participation, since it is linked to an expanding AS in the Brazilian market (VARÃO et al., 2017). With the steady growth in biodiesel blending percentages to diesel, it is evident that, in the short term, domestic beef tallow production may be able to assist in strategies for diversifying raw materials in a sustainable way. From the reported data, several favorable aspects are noticed as well as some limitations regarding the potential use of beef tallow for biodiesel production (Chart 5).

Chart 5. Favorable aspects and limitations regarding the potential use of beef tallow for biodiesel production.

Favorable Aspects	**Limitations**
• Immediately available in agro-industrial areas and not seasonally. • High yield of beef tallow in oil. • It does not compete with food production because it is a waste. • It is an alternative of correct destination for this waste, whose pollutant potential is high and often represents an environmental problem. • Plentiful raw material throughout the Brazilian territory.	• Low quality beef tallow represents additional costs to biodiesel plants as well as the production of a poor-quality biodiesel. • The lack of coordination of the AS that involves biodiesel plants is a limitation for the beef tallow commercialization.

Source: Adapted from (LEVY, 2011; BARROS & JARDINE, 2017; BELLO & DANIEL, 2015; CUNHA et al., 2009).

5. Conclusions

The use of beef tallow as a raw material for energy purposes is a reality in Brazil and has been gaining more space. This is mainly due to some advantages such as low price, residual raw material, high percentage conversion to oil, non-seasonal supply, no competition with food and good quality of the final biodiesel when compared to biodiesel from vegetable origin.

Although beef tallow biodiesel is energy-efficient, industry efforts are required to meet the quality specifications required by the ANP. Thus, the use of beef tallow as a raw material for fuel production can be a profitable outlet for the use of this waste, regarding the beef AS and the biodiesel AS.

Beef tallow is a raw material that has a high degree of use in production, which represents a possibility of investment that can be economically viable. In the social dimension, with respect to the National Program (PNPB), bovine tallow through the Social Fuel Seal was inserted in the biodiesel agro-industrial system, which may contribute to the strengthening of family agriculture that occur throughout the country, which can be investigated by a future work.

Although Brazil is among the largest producers of beef in the world and beef tallow is the second most used raw material for biodiesel production, there is a need for further investigations related to the competitiveness of beef tallow biodiesel, as well as analysis of sustainability in the various Brazilian regions, which is proposed as suggestions for a future work.

Additionally, the lack of coordination among agents in this productive chain can be a limitation for the beef tallow commercialization. The low-quality of beef tallow also represents additional costs to biodiesel plants. Therefore, future research and policies in this path could be helpful to overcame some of these challenges.

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