



Calorific value of Canadian forest residues estimated by proximate and ultimate analysis

Poder calorífico de resíduos florestais canadenses estimado por análise imediata e elementar

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ABSTRACT

The Canada has one of the cleanest energy matrices in the world, with 80% of electricity coming from non-greenhouse gas emitting sources. Among renewable sources, hydropower is the most important. However, the ample supply of renewable forest biomass could increase the share of biomass-based energy in Canada. Given the importance of Canadian forest residues as a renewable energy source, this study aimed to determine the High Heating Value of this biomass through literature correlations, using proximate and ultimate analysis data, and to verify the impact of moisture content on the Low Heating Value parameter. Using ultimate analysis data, the estimated High Heating Value was 18.80 MJ/kg, which is closer to the experimental values found in the literature for forest residues and woody biomass. The moisture content had a negative impact on the Low Heating Value, which decreased as the water content of the biomass increased, from 17.72 MJ/kg (without water) to 7.60 MJ/kg when the forest residue had 50% moisture content.

Keywords: Bioenergy; Empirical Correlations; Forest Biomass; Moisture Content; Renewable Energy.

RESUMO

O Canadá possui uma das matrizes energéticas mais limpas do mundo, com 80% da eletricidade proveniente de fontes que não emitem gases de efeito estufa. Entre as fontes renováveis, a mais importante é a hídrica. Entretanto, o amplo suprimento de biomassa florestal renovável pode aumentar a participação de energia proveniente de biomassa no cenário canadense. Considerando a importância dos resíduos florestais canadenses como fonte de energia renovável, esse estudo determinou o poder calorífico superior dessa biomassa através de correlações da literatura que utilizam dados de análise elementar e imediata, e verificou o impacto do teor de umidade no poder calorífico inferior. A estimativa por meio dos dados da análise elementar resultou em um poder calorífico superior de 18,80 MJ/kg, valor próximo aos experimentais encontrados na literatura para resíduos florestais e biomassa lenhosa. O teor de umidade teve impacto negativo no poder calorífico inferior, com esse parâmetro diminuindo com o aumento do conteúdo de água da biomassa, saindo de um valor de 17,72 MJ/kg (isento de água) e chegando a 7,60 MJ/kg quando o resíduo florestal apresentou 50% de umidade.

Palavras-chave: Bioenergia; Biomassa Florestal; Conteúdo de Umidade; Correlações Empíricas; Energia Renovável.

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1 INTRODUÇÃO

Since 2020, investments in clean energy have increased, including in low-emissions power, grids, low-emissions fuels, and efficiency in the end-use sector. In 2024, this set of actions represented more than US\$2 trillion in global energy-related investments, accounting for over 60% of total investment in the energy sector, which was US\$3.2 trillion (IEA, 2025).

The Canadian electrical matrix was one of the cleanest in the world in 2024, with 80% of electricity coming from non-greenhouse gas emitting sources. Among renewable sources, the most important was water, which supplied 55.1% of Canada's electricity generation, followed by nuclear (13%), but the growth was primarily driven by increased wind power generation capacity, which represented 7.6% of the electricity generation (Natural Resources Canada, 2026). However, despite having 3.69 million km² of forest land, about 9% of the world's total, and the potential to generate approximately 21 million Oven Dry Tons of forest residues, electricity generation from biomass in Canada was less than 2% (Natural Resources Canada, 2025; Karayel; Dincer, 2025; Pradhan *et al.*, 2022).

The Canadian government's most recent measure to promote the development of clean energy technologies was the launch, in June 2021 and renewed in 2024, of the Clean Fuels Fund (CFF). Over five years, US\$1.5 billion has been invested in biomass supply chains (new or existing) capable of aggregating, processing, handling, and storing a variety of biomass feedstocks (e.g., forest residues, municipal solid waste, and agricultural crop residues) from multiple locations and sources in an economical and sustainable manner, to facilitate their availability and use in the production of clean fuels (Natural Resources Canada, 2024).

The economic, social, and environmental benefits of using biomass energy make it a viable alternative for the partial and gradual replacement of fossil fuels. Notable economic and social benefits include job creation, revenue generation for municipalities, and energy independence since energy can be produced regionally. As for the environmental benefits, it is important to mention the reduction of sulfur oxides, hydrocarbons, carbon monoxide, and carbon dioxide emissions into the atmosphere, caused by burning fossil fuels, as well as the possibility of recycling organic waste and using forest biomass from reforestation. In this context, Canada's vast forested area makes it a country with excellent potential for using biomass from forest resources (timber-productive forest, forest residues, and wood residues) (Natural Resources Canada, 2026; Natural Resources Canada, 2025; Yu *et al.*, 2024). However, to effectively use forest residues as a source of renewable energy, their energy properties must be studied, especially their calorific value.

Calorific value is an important parameter for the application of biomass in conversion processes, such as gasification, pyrolysis, and combustion, because it has a significant impact on the energy and economic efficiency of these processes. It is a measure of the amount of energy released during the complete combustion of a unit of mass, and is therefore expressed as a unit of energy/unit of mass. It is classified as

High Heating Value (HHV) when referring to all the heat released by combustion, including the latent heat of water vaporization with all the resulting water in a liquid state; and Low Heating Value (LHV), which depends on HHV, when referring to the amount of heat released when a material combusts with all the resulting water in a vapor state (Rahman *et al.*, 2024; Lee, 2017; Natural Resources Canada, 2016).

A high water content affects the calorific value of biomass, as the energy for its vaporization comes from the biomass during combustion, lowering the HHV and, consequently, the LHV (Natural Resources Canada, 2016; Ferreira *et al.*, 2014). Because of this, biomasses with high moisture content, such as forest residues from this work, and sugarcane bagasse, for example, both with 50% moisture, have low HHV values (20.14 MJ/kg and 19 MJ/kg, respectively) and LHV values (19.16 MJ/kg and 16 MJ/kg, respectively) (Phyllis Database, 2025; Correia *et al.*, 2020).

Because biomass consists of many different molecules, the HHV of a fuel is determined experimentally in a calorimetric bomb that measures the amount of energy released during combustion. Furthermore, the HHV of solid fuels can be estimated using proximate analysis data – Fixed Carbon (FC), Volatile Matter (VM), and Ash, essential elements for understanding the industrial implications of biomass use, such as soil amendment or as a solid fuel. Alternatively, HHV can be estimated using ultimate analysis data, which is the composition of a fuel in terms of its basic elements – Carbon (C), Hydrogen (H), Nitrogen (N), Sulfur (S), and Oxygen (O), which are important for understanding the energy yield of biomass, its combustion characteristics, and its potential environmental impact (Sharma *et al.*, 2024; Racero-Galaraga *et al.*, 2024; Silva; Teixeira; Teixeira, 2023; Eichler *et al.*, 2017;).

Considering the importance of calorific value as a key parameter for achieving maximum performance of biomass for energy needs (e.g., conversion into biofuels and/or for energy production), the present study aimed to estimate the calorific value of Canadian forest residues through empirical correlations from the literature, using proximate and ultimate analyses, and to analyze the impact of moisture content on calorific value.

2 MATERIALS AND METHODS

2.1 HHV CORRELATIONS

The HHV parameter was determined from two empirical correlations - Equation (1) and Equation (2).

Equation (1), proposed by Parikh, Channiwala and Ghosal (2005), estimates the calorific value using proximate analysis data. The correlation was derived using 450 data points, and another 100 data points were used for its validation, which made the model applicable to a wide range of solid carbonaceous biomasses, with an absolute error of 3.74% relative to the measured HHV values.

$$HHV = [(0.3536 \times \% FC) + (0.1559 \times \% VM) - (0.0078 \times \% Ash)] \quad (1)$$

Where:

HHV = High Heating Value, dry basis (MJ/kg)

FC = Fixed Carbon, dry basis (%)

VM = Volatile Matter content, dry basis (%)

Ash = Ash content, dry basis (%)

Equation (2) is a unified correlation based on the elemental composition of fuels (C, H, O, N, S, and ash). For this model, Channiwala and Parikh (2002) used 225 data points for derivation and 50 data points for correlation validation. This equation provides an accurate estimate of the HHV of fuel, on a dry basis, for various solid-liquid-gaseous biomasses using ultimate analysis data, with an absolute error of 1.45% relative to the measured HHV values.

$$HHV = (0.3491 \times \% C) + (1.1783 \times \% H) - (0.1034 \times \% O) - (0.0151 \times \% N) + (0.1005 \times \% S) - (0.0211 \times \% Ash) \quad (2)$$

Where:

HHV = High Heating Value, dry basis (MJ/kg)

C = Carbon content, dry basis (%)

H = Hydrogen content, dry basis (%)

O = Oxygen content, dry basis (%)

N = Nitrogen content, dry basis (%)

S = Sulfur content, dry basis (%)

Ash = Ash content, dry basis (%)

The limitations of these correlations can be found in the original studies by Parikh, Channiwala and Ghosal (2005) and Channiwala and Parikh (2002), and do not apply to the biomass studied herein (forest residues).

2.2 LHV CORRELATION

During the combustion process, if water vapor is not condensed, as occurs in traditional boilers or dryers, the heat of condensation is lost when the combustion gases and water vapor escape into the atmosphere. This heat of combustion minus the heat of condensation of water is called LHV, also known as the net calorific value (Lee, 2017; Natural Resources Canada, 2016).

The LHV parameter was determined by Equation (3) (Prates *et al.*, 2023; Habitzreiter *et al.*, 2019; Ferreira *et al.*, 2014):

$$LHV = HHV - (h_g \times 0.09 \times \% H) \quad (3)$$

Where:

LHV = Low Heating Value, dry basis (MJ/kg)

HHV = High Heating Value, dry basis (MJ/kg)

H = Hydrogen content, dry basis (%)

hg = latent heat of steam in the same units as HHV (MJ/kg)

2.3 LHV VERSUS MOISTURE CONTENT

The LHV of wet forest residues at different moisture contents was defined as “LHV_{MC}” and estimated using Equation (4).

The LHV_{MC} is the amount of low heat released minus the amount of heat required to evaporate formation water and moisture from the fuel (Ferreira *et al.*, 2014).

$$LHV_{MC} = [LHV \times (1 - (0.01 \times \% MC))] - (6 \times \% MC) \quad (4)$$

Where:

LHV_{MC} = Low Heating Value in moisture content “MC” (MJ/kg)

LHV = Low Heating Value from Equation (3), dry basis (MJ/kg)

MC = moisture content, wet basis (%)

2.4 PROXIMATE AND ULTIMATE ANALYSIS DATASET

Data from the literature on proximate and ultimate analyses show a wide range of values for woody biomass. Table 1 lists some minimum and maximum values from the literature, as well as the data used in this study.

Table 1. Range of minimum and maximum values for proximate and ultimate analysis data of woody biomass, as described in the literature

Proximate Analysis (%wt, dry basis)		
	Literature	Phyllis Database*
Fixed Carbon	6.2 – 23.5	13.6
Volatile Matter	75.35 – 87.80	82.4
Ash	0.10 – 4.7	4.0
Ultimate Analysis (%wt, dry basis)		
Carbon	43.10 – 55.90	50.3
Hydrogen	4.6 – 7.55	4.6
Oxygen	35.10 – 50.18	40
Nitrogen	0.08 – 3.21	1.0
Sulphur	0 – 0.99	0.1
Chlorine	150 – 400 mg/kg	400 mg/kg

Sources: Phyllis Database (2025), Eichler *et al.* (2017), Lira *et al.* (2025); Prates *et al.* (2023); Silva, Teixeira and Teixeira (2023); Habitzreiter *et al.* (2019); Eichler *et al.* (2017); Acquah *et al.* (2016), Parikh, Channiwala and Ghosal (2005), Channiwala and Parikh (2002). Note: *Data used in this study.

The proximate and ultimate analysis data used for the calorific value estimates in this study were obtained from the Phyllis Database (2025) (Table 1). This database provides a section with specific information on forest residues, which fall within the range reported in the literature on woody biomass.

2.5 RELATIVE PERCENTAGE ERROR

The relative percentage error (RPE) was calculated to assess the accuracy with which the models used reflected the experimental HHV and LHV values from the literature on woody biomass.

The RPE was calculated as:

$$\text{RPE (\%)} = \left| \left[\frac{(m_c - m_L)}{m_L} \right] * 100 \right| \quad (5)$$

Where:

RPE = relative percentage error (%)

m_c = calorific value calculated from equations (1), (2), or (3)

m_L = experimental calorific value of woody biomass (literature)

3 RESULTS AND DISCUSSION

3.1 HEATING VALUES OF CANADIAN FOREST RESIDUES

The results of the HHV estimated from empirical correlations, Equation (1) and Equation (2), using proximate and ultimate analysis data (Table 1), respectively, are presented in Table 2. For comparison purposes, some experimental values of HHV from the literature on woody biomass are presented in the same table, as well as the relative percentage error.

Table 2. HHV values for Canadian forest residues estimated from empirical correlations and experimental values of woody biomass (literature) for comparison

Type of biomass	HHV (MJ/kg, dry basis)	Reference	RPE (%) (HHV _{Eq.(1)})	RPE (%) (HHV _{Eq.(2)})
Forest residues	17.60	This work – Equation (1)	---	---
Forest residues	18.80	This work – Equation (2)	---	---
Forest residues	20.14	Phyllis Database (2025)	12.61	6.65
Forest residues (Blend 1 - trunks, branches, and leaves)	19.59	Lira <i>et al.</i> (2025)	10.16	4.03

Type of biomass	HHV (MJ/kg, dry basis)	Reference	RPE (%) (HHV _{Eq.(1)})	RPE (%) (HHV _{Eq.(2)})
Forest residues (Blend 2 - trunks, branches, and leaves)	18.63	Lira <i>et al.</i> (2025)	5.53	0.91
Forest residues (Blend 3 - trunks, branches, and leaves)	18.96	Lira <i>et al.</i> (2025)	7.17	0.84
Forest residues (<i>E. saligna</i>)	18.67 to 19.46	Prates <i>et al.</i> (2023)	5.73 to 9.56	0.70 to 3.39
Forest residues (<i>E. urophylla</i> and <i>E.</i> <i>grandis</i>)	18.54 to 19.20	Prates <i>et al.</i> (2023)	5.07 to 8.33	1.40 to 2.08
Forest residues (Pine – trunk)	19.10	Silva, Teixeira and Teixeira (2023)	7.85	1.57
Forest residues (sugar maple, red oak, and red maple)	19	Acquah <i>et al.</i> (2016)	7.37	1.05
Forest residues (aspen, sugar maple, and basswood)	18.8	Acquah <i>et al.</i> (2016)	6.38	0.00
Branches (<i>E. grandis</i> and <i>E.</i> <i>urophylla</i>)	18.97	Habitzreiter <i>et al.</i> (2019)	7.22	0.90
Wood (<i>E. grandis</i> and <i>E.</i> <i>urophylla</i>)	18.39	Habitzreiter <i>et al.</i> (2019)	4.30	2.23
Eucalyptus species (<i>E. urophylla</i>)	19.10	Eichler <i>et al.</i> (2017)	7.85	1.57
Eucalyptus species (<i>E. saligna</i>)	19.10	Eichler <i>et al.</i> (2017)	7.85	1.57
Eucalyptus species (<i>E. dunnii</i>)	19.15	Eichler <i>et al.</i> (2017)	8.09	1.83

Note: Equation (1) from Parikh, Channiwala and Ghosal (2005); Equation (2) from Channiwala and Parikh (2002); RPE was calculated using Equation (5).

As shown in Table 2, the HHV estimated from the proximate analysis data (HHV_{Eq.(1)} = 17.60 MJ/kg) is far from the experimental HHV values for forest residues in the Phyllis Database (2025), Lira *et al.* (2025), Prates *et al.* (2023), Silva, Teixeira and Teixeira (2023), and Acquah *et al.* (2016) studies, with a relative percentage error exceeding 5.07% and reaching 12.61%. Even compared to other woody biomass, this value shows an RPE greater than 4.30%. On the other hand, the HHV calculated from the ultimate analysis data (HHV_{Eq.(2)} = 18.80 MJ/kg) is closer to the experimental values for forest residues from the literature (RPE from 0% to 6.65%). This value is also close to the HHV values for branches and wood (RPE = 0.90% and 2.23%, respectively) (Habitzreiter *et al.*, 2019), and for eucalyptus species with an RPE from 1.57% and 1.83% (Eichler *et al.*, 2017).

The LHV value calculated by Equation (3) was 16.6 MJ/kg, when the $HHV_{Eq.(1)}$ value was used. This value is lower than the experimental LHV value for forest residues in the Phyllis Database (2025) (LHV = 19.16 MJ/kg; RPE = 13.36%), Prates *et al.* (2023) (LHV = 17.32 to 18.21 MJ/kg; RPE = 4.15% to 8.84%, respectively), and Lira *et al.* (2025) (LHV = 18.36, 17.39, and 17.72 MJ/kg; RPE = 9.59%, 4.54%, and 6.32%, respectively).

The LHV using the $HHV_{Eq.(2)}$ (ultimate analysis data) was 17.70 MJ/kg. This value is closer to the LHV values for forest residues in Prates *et al.* (2023) (RPE = 2.19% to 2.8%) and Lira *et al.* (2025) (RPE = 3.59%, 1.78% and 0.11%, respectively) studies, but is lower than the LHV for forest residues in the Phyllis Database (2025) (RPE = 7.62%). This value is also close to the LHV of branches (LHV = 17.90 MJ/kg; RPE = 1.12%) and wood (LHV = 17.26 MJ/kg; RPE = 2.55%) (Habitzreiter *et al.*, 2019).

The results in Table 2 confirm that the correlation using ultimate analysis, Equation (2), fits best when comparing the HHV result with the experimental calorific values found in the literature for woody biomass. This behavior is related to the elements presented in the ultimate analysis, which describes the percentages of C, H, O, N, and S. Carbon, hydrogen, and oxygen content allow for the estimation of the calorific value and constitute the main elements of biomass. They are the main combustible fraction of waste, as carbon and hydrogen react with oxygen during combustion and determine the energy content of biofuels. Therefore, the HHV from solid biomass is higher when it has a higher carbon and hydrogen content and a lower oxygen content (Bianchini *et al.*, 2025; Sharma *et al.*, 2024; Rahman *et al.*, 2024; Eichler *et al.*, 2017).

Lignocellulosic biomass generally contains carbon, oxygen, and hydrogen in amounts of 30–60%, 30–45%, and 4–6% of the dry mass, respectively. Nitrogen, sulfur, and chlorine are found in smaller quantities in biomass (generally less than 1%) and are related to environmental impacts, such as the production of nitrogen oxides, gaseous sulfur dioxide, and particulate emissions, among others (Alruqui *et al.*, 2024; Timilsina *et al.*, 2024; Garba, 2021).

In turn, proximate analysis data refer to the fixed carbon, volatiles, and ash present in biomass, all of which are important elements in choosing the best thermal process for biomass conversion, as they affect energy efficiency (Bianchini *et al.*, 2025; Rahman *et al.*, 2024; Eichler *et al.*, 2017; Ferreira *et al.*, 2014). Biomasses with high VM content lose part of their mass in the form of volatiles and consequently may emit less heat. Fixed carbon, what remains after moisture and volatiles are removed, indicates the energy potential of biomass (Racero-Galaraga *et al.*, 2024; Sharma *et al.*, 2024; Silva; Teixeira; Teixeira, 2023). It is also important to know the amount of biomass ash because a high non-combustible portion (ash) can cause fouling, sintering, slag deposition, and agglomeration in industrial machinery used for conversion processes, like pyrolysis (Abioye *et al.*, 2024; Puri; Hu; Naterer, 2024). Ash content may increase due to the presence of bark soil, sand, or when the biomass is in contact with inorganic additives, as well as chemical treatments before use (Natural Resources Canada, 2016). In general, wood residues have a lower ash content and a slightly higher HHV than field crops. For this reason, in Canada, forest residues are the most common

renewable feedstock used in pyrolysis for fuel generation compared to agricultural biomass (Puri; Hu; Naterer, 2024; Bianchini *et al.*, 2025).

It is important to note that there are many correlations in the literature for estimating HHV and LHV from ultimate and proximate analyses. In this study, Equation (1) and Equation (2) were chosen based on the low absolute error of the models and their applicability to various solid carbonaceous biomasses, a category that includes forest residues. Since these equations use different compositions, their results may vary for each type of solid fuel, even within a specific biomass category (Lira *et al.*, 2025; Eichler *et al.*, 2017; Ferreira *et al.*, 2014; Parikh; Channiwala; Ghosal, 2005; Channiwala; Parikh, 2002). Furthermore, as shown in Table 1, the heterogeneity of lignocellulosic woody biomass may lead to variations in proximate and ultimate data reported, which may affect the calorific value results obtained by both equations in this study (Lira *et al.*, 2025; Bianchini *et al.*, 2025; Daskin *et al.*, 2024).

Simpler algebraic models for estimating HHV, which offer broad applicability across various materials, are the most widely used in the literature. However, proximate analysis provides information about some basic properties, but does not offer a complete characterization of the material as done by ultimate analysis. Therefore, models that use proximate analysis may be mathematically questionable, since FC is determined by the difference of 100% and the sum of the VM and ash (dry weight), as in the Equation (1), and any measurement error (VM or ash) is automatically transferred to the FC value. This, along with the high relative percentage error obtained using Equation (1), may explain the difference between the calorific value result of this study and the experimental values reported in the literature. On the other hand, models based on ultimate analysis, such as Equation (2), are preferred because they are simpler and applicable to diverse biomass types, and because the energy content of biomass is primarily influenced by its chemical composition (C, H, and O) (Lira *et al.*, 2025; Bianchini *et al.*, 2025; Daskin *et al.*, 2024; Ardila; Figueroa; Maciel, 2024; Silva; Teixeira; Teixeira, 2023; Vargas-Moreno *et al.*, 2012).

3.2 IMPACT OF MOISTURE CONTENT ON LHV

Equation (4) was applied to different moisture contents to analyze their impact on the LHV of forest residues. The results are illustrated in Figure 1.

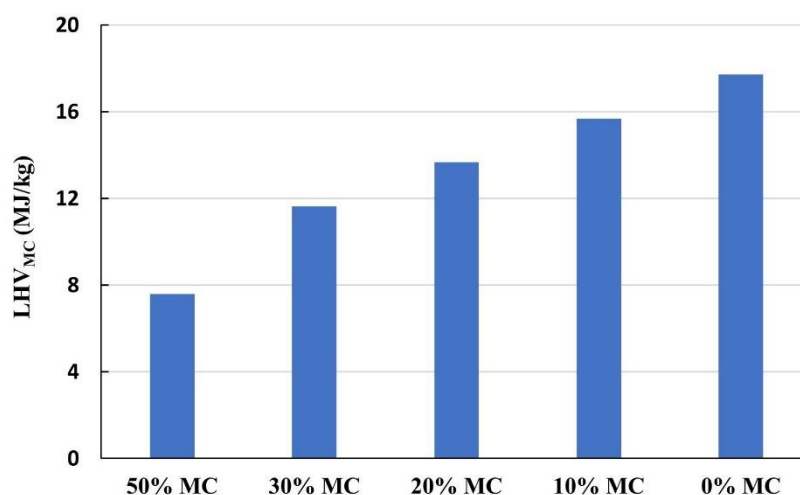


Figure 1. Impact of MC (% wet basis) on LHV (MJ/kg)

Note: Diagram prepared by the authors based on Equation (4)

Figure 1 shows that LHV_{MC} decreases with increasing moisture content in the biomass. LHV_{MC} decreases from 17.72 MJ/kg (without water) to 7.60 MJ/kg when the forest residue contains 50% moisture content. Lira *et al.* (2025) reported a similar trend for forest residues under similar moisture conditions, with LHV_{MC} values of 15.5 MJ/kg and 8 MJ/kg for MC = 10% and 50% (wet basis), respectively. Boundy *et al.* (2011) found LHV_{MC} of 19.4 MJ/kg and 8.5 MJ/kg for poplar with 0% and 50% of MC (wet basis), respectively, and Ferreira *et al.* (2014) determined LHV_{MC} of 7.2 MJ/kg and 7.3 MJ/kg for pine barks and chips, respectively, both with 55% of MC (wet basis).

The water in the biomass, expressed by its moisture content, is one of the factors that most influences energy release. Therefore, biomass with a high moisture content, such as forest residues, has low HHV and LHV values because moisture content negatively impacts the calorific value (Figure 1). This is because, during combustion, more energy is required to initiate the burning process; that is, more energy is needed to vaporize the water, and less energy is supplied to the exothermic reaction (combustion), increasing biomass consumption (Bianchini *et al.*, 2025; Karayel; Dincer, 2025; Racero-Galaraga *et al.*, 2024; Raina *et al.*, 2022). Since the evaporated water cannot be condensed to return heat to the system, working with biomasses that have lower moisture content is important to obtain better calorific values and greater efficiency in conversion processes, making them competitive with fossil fuels, which have the advantage of presenting higher calorific values, such as liquefied petroleum gas (HHV = 50.15 MJ/kg; LHV = 46.61 MJ/kg) and petroleum coke (HHV = 31.31 MJ/kg; LHV = 29.5 MJ/kg) (Silva *et al.*, 2025; Natural Resources Canada, 2016; Ferreira *et al.*, 2014; Boundy *et al.*, 2011).

4 FINAL CONSIDERATIONS

The HHV correlation using ultimate analyses, Equation (2), provided result consistent with previous studies in the literature. The HHV value of 18.80 MJ/kg is

closer to the experimental HHV values found in the literature for woody biomass, with a relative percentage error between 0.00 and 6.65%. The same trend was observed for the LHV results (17.70 MJ/kg and RPE from 1.12% to 7.62%). Based on the obtained results, it can be concluded that the model using ultimate analyses can be effectively applied to predict the calorific value of Canadian forest residues.

Additionally, the moisture content negatively impacted on the LHV value; this parameter decreased as moisture content increased, ranging from 17.72 MJ/kg (without water) to 7.60 MJ/kg when the forest residue had 50% moisture content. For this reason, biomass should be as dry as possible for energy applications, as LHV tends to increase with lower moisture content.

LHV and HHV, along with moisture content, are important parameters that indicate the potential of forest residues for thermochemical conversion processes. Ultimate and proximate analyses data provide essential information on the biomass's ability to achieve optimal efficiency in these processes. HHV allows us to predict fuel consumption and the energy output of the material. LHV is used for thermal calculations and determines the volume of material needed to feed burners and boilers, for example. Therefore, accurate HHV and LHV values are fundamental to establishing the best application of biomass since these parameters impact the energy cycle.

It is important to note that the empirical literature correlations for HHV and LHV found in the literature have limitations since they are generally tested within a restricted range of biomasses and proximate and ultimate analysis data. Therefore, the choice of one correlation over another should take into account the accuracy of the proximate and ultimate analysis data, as well as the applicability of the models, with a low margin of error, to a wide range of biomasses and/or whether the correlation has been tested for a specific material, to reduce the risk of extrapolating the dataset on which the models were tested.

The use of forest residues as an energy source in Canada is fundamental for developing new renewable energy alternatives. However, the moisture content of Canadian forest residues harms the combustion and interferes with the efficiency of converting biomass into biofuel. Therefore, to increase the share of this biomass in the energy matrix, long-term research and planning are needed to improve processes, study methods to reduce the moisture content of forest biomass to improve the material calorific value, and encourage investment in the sector, especially if an integrated drying process can be considered in a forest biomass biorefinery.

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