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# Short rotation forestry feedstock: Influence of particle size segregation on biomass properties

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## HIGHLIGHTS

- SRF is highly heterogeneous, due to presence of bark and occasionally foliage.
- The younger the SRF is harvested, the more heterogeneous is the feedstock.
- Particle size fractions from ground SRF are affected by the heterogeneity.
- Fine particles below 0.2 mm are particularly well differentiated.
- Removal of fine particles can improve suitability for thermochemical conversion.

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## ABSTRACT

Short rotation forestry (SRF) is a promising feedstock for production of biofuels via the thermochemical route. Five poplar biomasses (SRF of different clones and ages, and debarked wood) were ground and separated into three particle size fractions: <0.2 mm; 0.2–0.4 mm; >0.4 mm. The characterization of these samples was performed to evaluate the quality and homogeneity of SRF feedstocks. Some major properties related to thermochemical processes were measured: chemical composition, organic and inorganic elemental compositions. The heterogeneity in SRF feedstock properties, resulting from high bark content, appeared to be transferred to particle size fractions. The results obtained highlighted that fine particles below 0.2 mm had very specific properties, close to those of bark. The removal of this fraction would result in a more homogeneous feedstock, avoiding the issue caused by segregation risk for process stability. Such removal of small particles would also modify the biomass properties by reducing bark amount, improving the suitability of SRF feedstock for thermochemical conversion.



## 1. Introduction

Thermochemical processing is a very efficient route for producing bioenergy from lignocellulosic biomass. The direct combustion is currently the most popular process but the interest for other thermochemical processes such as gasification or pyrolysis is growing fast [1]. The production of energy by thermochemical conversion of biomass is increasing worldwide and requires the biomass supply to increase as well. To enable such large scale biomass supply, some efforts are focused on diversification of biomass feedstocks. In this context, the energy crops have a good potential for regular and large scale lignocellulosic biomass production [2]. Among energy crops, short rotation forestry (SRF) could be a promising feedstock for the thermochemical conversion sectors [3–6]. It offers the possibility of a regular supply of biomass that is close to wood in terms of composition: that makes SRF particularly interesting to diversify supply of the current wood-based energy production. Also, SRF would only slightly competes with other sectors such as the food industry or the forestry timber. SRF consists to dense plantations of trees, regularly harvested: 1–5 years rotation for recent bioenergy purposes, and up to 10 years in a more classical growth model like the one used for pulpwood production [7]. Poplar is one of the most common SRF trees in temperate areas like France, due to the fast regrowth of its shoots and its good suitability to cultivation conditions, despite its susceptibility to pests [8,9].

In order to optimize the thermochemical conversion of diversified feedstocks, biomass pretreatment steps must be efficiently designed and well chosen: drying, grinding, pelletization, flash

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pyrolysis and torrefaction [10–13]. The application of these pretreatments has to be adapted to the biomass type and to the technology used for biomass conversion or to the production objectives. Anyway, drying or grinding are essential for most of the process chains. Grinding is an easy step to include in the basic industrial process chain, but it can also have significant impact on biomass properties. Indeed, particle size segregation of the ground biomass can occur during the transportation or conversion steps, thus modifying the properties or creating heterogeneity in the sample [14,15]. Such modifications and heterogeneity of biomass properties may then have a noticeable impact on studies about understanding and modeling of further thermochemical processes. Poplar SRF contains both wood and a significant amount of bark, that makes it a particularly heterogeneous biomass. Wood and bark fractions of SRF poplar are known to have different characteristics and behavior during thermochemical treatment: mass loss kinetics, composition of the products released [16,17]. Particle size segregation would then be a particularly relevant issue concerning the use of SRF feedstocks for thermochemical conversion.

Several biomass properties are known to have an impact on thermochemical processes. Depending on the process considered, it can be organic elemental composition, structural lignocellulosic composition or ash yield and inorganic elemental composition, among others [18–21]. The accurate knowledge of these properties is required for studies that aim to understand and model the impact of biomass properties on process reactions, products yields, etc. If some industrial processes can be more flexible in regard to accuracy of biomass characterization, the control of properties remain critical for many processes. The stability of properties can also be required during the conversion of a feedstock, to ensure constant quality of products. Increasing the flexibility of a process in regards to the range of biomass properties acceptable, or having real-time adaptation of conditions of processing to the biomass properties changes can be quite expensive. An accurate control on biomass properties would also enable advanced applications such as biomass blending to improve biomass suitability to processes.

This study focuses on the control of properties variability within a SRF feedstock. Sources of variability can be classified according to their origin and associated possibilities of control. The natural variability of a biomass feedstock, linked to its growing conditions and to its natural diversity, is an unavoidable processing constraint. For the poplar SRF feedstock considered, natural variability can be illustrated with different poplar clones, grown on different soils and harvested at different ages. Previous studies have shown that the clonal species and age of SRF poplar tend to have a moderate influence on biomass properties and thermochemical treatments [16,22]. An other source of variability – that may be qualified as artificial – comes from the particle size segregation phenomena that can appear during transportation or conversion steps. In this study, the influence of grinding and segregation on SRF poplar physico-chemical properties was evaluated and compared to variability from cultivation conditions (clone, age, soil quality, etc.). This was achieved by dividing ground poplar samples into different particle size fractions which were then characterized. The analyses focused on some physico-chemical properties that are known to impact thermochemical processes: structural lignocellulosic composition, elemental organic composition, ash content and inorganic elemental composition [18–21]. The results will help to determine whether ground SRF poplar can be considered as a feedstock with homogeneous properties or not, thus impacting on further works of characterization, processing and modeling based on this biomass. This work will also provide information on the pertinence and efficiency of the currently used biomass sampling techniques and standards (XP CEN/TS 14780).

## 2. Materials and methods

### 2.1. Woody samples

The set of woody biomass samples used for this study was representative of the available French SRF poplar (*Populus* spp.) feedstocks: 4 SRF poplar of different ages and clones completed with poplar debarked wood Table 1. Two-year poplars 2*y-Po*(*a*, *b*, *c*) grown in the same place and older SRF 12*y-Po* grown in another place. All fields had similar latitude (about 49°) and similar alluvial soil. All samples were shredded and naturally dried in the field for some weeks, and then samples weighing some hundreds kg were taken for experiments. The woody chips were then industrially air-dried to 15–20% moisture content (wet basis) before being ground to millimetric particle size (hammer-mill for 1*y-Po*(*a*) and knife-mill for the others). Some kg of ground biomass were sampled at this point for study purposes. Debarked wood sample *Po–W* was obtained from mature poplar chipped and debarked as though for pulp–paper manufacture. The age of poplar was estimated about 30 years, grown in France on alluvial soil. Some kg of chips were sampled and ground (knife-mill) to millimetric size for study purposes.

The poplar samples were ground to obtain a common particle size distribution of sawdust Fig. 1, with average particle size of 1 mm. This type of sawdust is suitable for pellet production or for injection in some gasification reactor technologies. Each sample of ground poplar was then divided into 3 particle size fractions (small/<0.2 mm; medium/0.2–0.4 mm; large/>0.4 mm) by vibrating sieves (70 and 40 mesh sieves were used) with a method derived from standard XP CEN/TS 15149-2. These particle size fractions appeared to be relevant to the study of segregation phenomena, considering the initial particle size distribution of ground biomass. In addition to the set of poplar samples and their particle size fractions, a sample of bark was also characterized. This bark fraction (2*y-Po*(*a*)*-B*) was manually sampled from 2*y-Po*(*a*) SRF; bark mass fraction on a dry basis accounted for about 25% of the global sample weight of 2*y-Po*(*a*) while only about 10–15% for the older SRF 12*y-Po*. Finally, all samples were ground again to reach the particle size required for the different analyses: typically below 1 mm.

### 2.2. Analytical methods

The following analyses were performed on each particle size fraction, and also on non fractionated poplar samples. Unless otherwise specified, all results were given as mass fractions of dry material. The properties of these non-fractionated samples, termed "raw samples", were compared to those from reconstituted from fractions, to control analytical quality: $P_{rec} = X_{small} \cdot P_{small} + X_{medium} \cdot P_{medium} + X_{large} \cdot P_{large}$ ($P_{rec}$: reconstituted property, $P_{fraction}$ and $X_{fraction}$: property and weight percentage of small, medium and large particle size fractions).

- Proximate analysis: Moisture content was determined by a method derived from standard NF EN 14774. These data were used to express all results of the further analyses on dry basis.

**Table 1**
Origin (age and species) of poplar samples. *P.d*: Populus deltoides; *P.n*: Populus nigra; and *P.t*: Populus trichocarpa.

| Ref. | Feedstock | Species |
|---|---|---|
| 2*y-Po*(a) | SRF 2 years | *P.d* × *P.n* (I214) |
| 2*y-Po*(b) | SRF 2 years | *P.d* × *P.n* (Koster) |
| 2*y-Po*(c) | SRF 2 years | *P.d* × *P.n* (Dorskamp) |
| 12*y-Po* | SRF 12 years | *P.t* × *P.d* (Beaupré, Boelare) |
| *Po–W* | Wood 30 years | *P.d* × *P.n* (I214) |