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**Short Communication**

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# Proximate composition and thermal properties of hemp and flax fibres

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**Abstract**

Along with the apparel or clothing industry, diversified uses of natural lignocellulosic fibre are getting popularity in many fields e.g., composites, automotive, marines, aerospace, electronics, civil construction, nanotechnology, biomedical, etc. The property and uses of textiles are determined by their constituent fibre properties. The proximate composition and thermogravimetric analysis (TGA) data of a total of 9 local hemp and flax genotypes (3 and 6, respectively) were carried out to understand their suitability in different applications. A wide variation was observed in the ash content of hemp and flax fibres varied from 1.7 to 17.7%, crude protein 3.27 to 9.02%, crude fibre 26.51 to 55.32%, ether extract 2.6 to 20.9% and energy value 284.44 to 383.96 kcal $100^{-1}$ g. In TGA analysis, all the fibres showed a similar trend. The flax genotypes contain lower ash and ether extract and higher DM, crude carbohydrate and crude fibre than hemp genotypes. Therefore, flax could be used in the lightweight composite, textile, pulp and cellulose-based industries. The hemp fibre had higher ash which was reflected by a higher residue at 500$^{o}$C in TGA analysis. To understand the viability of these flax fibres, further investigations are needed.

**Keywords:** Crude protein; Crude fibre; Ash; Ether extract; Thermogravimetric analysis

## Introduction

Natural fibres (NFs), hairlike structures, originated from animals (hairs, wools, silks, etc.), plants (bast, leaf and husk fibres, seed hairs, etc.), or geological processes. These can be used as a component of composites, nonwoven fabrics e.g., felt or paper or, altered into yarns, into woven cloth. The NFs have many advantages in different aspects e.g., environmental pollution, health, etc. over artificial fibres. These NFs are renewable, carbon-neutral, biodegradable and also produce waste that is either organic or can be used to generate electricity or make ecological housing material towards the achievement of UN Sustainable Development Goals (# 12 Responsible Production and Consumption). The demand for commercial use of the NFs and fibre-based composites in various industrial sectors e.g., textile, pulp, automotive interior linings (roof, rear wall, side panel lining),

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furniture, construction, packaging, and shipping pallets, etc. for their better physicochemical and physicomechanical properties (Girijappa *et al.* 2019). The quality and use of a natural fibre may vary due to inherent variabilities in its natural components such as fibrous nature, fibre morphology, cellulosic, and non-cellulosic content, and key properties such as fibrous structure, spinnability, strength, fineness, dyeability, and the ability to react with acid or alkali (Shuvo, 2020).

Hemp (*Cannabis sativa* L.; Cannabaceae) and flax (*Linum usit at issimum* L.; Linaceae), two of the oldest cultivated fibre plants, fibres are singly or combined used for clothing and household textiles (Skoglund *et al.* 2013). Hemp has also various traditional uses in the Indian subcontinent such as fibre and roasted seeds eaten as a food. In Bangladesh, the hemp plant was cultivated for manufacturing three narcotic products called Ganja, Charas and Bhang (O'Malley, 1916); there are disagreements over the use of hemp fibres. According to O'Malley, hemp was cultivated on 8,000 acres (approx. 3,250 ha) of land of Sitakund on the banks of the Sangu River and in the southeast of Satkania on the banks of Tankabati for producing hemp fibre (O'Malley, 1908). Milburn initially mentioned that hemp has been cultivated in Bengal from time immemorial for intoxication (Milburn, 1813); but is never used by natives for cordage or cloth, as in Europe. However, he also pointed out later that when hemp is intended for cordage, the natives sow it very thin and afterwards transplant the young plants, placing them at a considerable distance from each other, often 2.75 or 3.0 m. The history of commercial hemp cultivation in Bangladesh has been discussed (Rahman *et al.* 2022). Hemp fibres are used in rope, textiles, garden mulch, an assortment of building materials and animal beddings, to fabricate different composites, and processed to form yarn or bundles (Girijappa *et al.* 2019). The history of linen production and use dates back to 12000 BC (Vedic age) to 1500 CE (Medieval period) in the Indian subcontinent, including India, Pakistan and Bangladesh <https:// agropedia.i itk.ac.in/ content/history-linen- indian-subcontinent>. Edible flaxseed dominated India's production rather than fibre flax; because other fibre species, such as hemp, were already in wide use (Judd, 1995). Flax fibres are used in furniture materials, textiles bed sheets, linen, interior decoration accessories, composite reinforcement, etc. (Girijappa *et al.* 2019; Baley, 2021).

The nutritional aspects of both hemp and flax seeds and different plant parts were reported in different publications (Muir and Westcott, 2003; Audu *et al.* 2014; Galasso *et al.* 2016; Waris *et al.* 2018; Ishag *et al.* 2019; Alonso-Esteban *et al.* 2022). Although the physical properties of hemp and flax fibres are known to us (Girijappa *et al.* 2019), hitherto, no information on the proximate composition of fibres of Bangladeshi genotypes of these two important fibre-yielding crops is available. The constituent fibre properties influence application of textiles in many fields e.g., composites, automotive, marines, aerospace, electronics, civil construction, nanotechnology, biomedical, as well as the apparel or clothing industry (Shuvo, 2020). We have, therefore, reported the proximate composition and thermogravimetric analysis data of 3 hemp and 6 flax genotypes here.

**Materials and methods**

The proximate analysis and thermogravimetric analysis (of fibres) of six flax genotypes and three hemp genotypes were carried out to understand their suitability in different applications. Hemp seeds were collected from different locations in Bangladesh (detailed collection information will be available upon request) and the genotypes are named accordingly, *viz*. Brammonbaria, Chittagang and Meherpur. The hemp plants were grown (in a confined area) at Botanical Garden, Department of Crop Botany, Bangladesh Agricultural University. Flax fibres were collected with the ribbon retting method (Roy *et al.* 2010) and sun-dried properly. The flax fibres of 6 genotypes, harvested from another experiment in the same year, were collected from the Laboratory of Plant Systematics of the same Department.

The proximate composition analysis *viz*. dry matter (DM), crude protein (CP), crude fibre (CF), ash and ether extract (crude fat; EE), were accomplished at the Laboratory of Department of Animal Science, Bangladesh Agricultural University, Mymensingh following standard procedure (Kabir *et al.* 2018).

The crude carbohydrate was calculated following Mundaragi *et al.* (2017).

Crude Carbohydrate (%) = 100 – [moisture (%) + protein (%) + fibre (%) + fat (%) + ash (%)]

The calorific value or the total energy value of fruits in kcal$100^{-1}$ g was calculated with the help of the following equation (European Parliament and Council of the European Union, 2011).

Energy value (kcal $100^{-1}$ g) = 4 × Protein + 9 × Fat + 4 × Carbohydrate + 2 × Fibre

Thermogravimetric analysis (TGA) was performed by a thermal analyzer of SII TG/DTA 6300. Thermal analysis was carried out in the temperature range of 30–500°C with a programmed heating rate of 20°C min$^{-1}$. The inertness of the heating chamber was maintained with continuous nitrogen gas flow at 100 ml min$^{-1}$. The test was performed with a 5 to 8 mg ground sample in the platinum crucible.

**Results and discussion**

*Proximate analysis*

Distinct differences in all the proximate components were observed between fibre of hemp and flax genotypes except the DM content. The results revealed a close similarity in the DM content of hemp and flax fibres which varied from 96% to 97.1% (Table I). High DM content in fibre cells indicates that these are rich in structural components – carbohydrates, protein, fats, minerals, etc. except water. The density of hemp and flax fibres was the same or very similar and low (1.4–1.5 g cm$^{-3}$) which could be a great choice for light-weight composite structures (Misnon, 2014). Low-density fibre has enormous implications in technical textile industries, especially in aerospace and automotive applications for reducing fuel consumption and related fuel costs (Shuvo *et al.* 2020). A careful selection of cultivars (/genotypes) would allow for the optimizing utility of this fibre feature (Shuvo, 2020).

Ash content was analyzed in the range of 1.7% to 17.7% and a significant difference was observed between hemp (12.5–17.7%) and flax (1.7–3.8%) genotypes. The maximum ash was found in hemp genotype Meherpur and the minimum in flax genotype Chilmari. Ash is the residue left after all the moisture and organic matter has been removed at high temperatures. The high ash content of these fibres is a measure of mineral richness (Lai and Roy, 2004).

The maximum quantity of CP, EE and energy value was found in hemp genotypes and minimum in flax genotypes. Fibres of two flax genotypes, *viz*. BD-10708 and BD-1903, contained an exceptionally higher amount of ether extract compared to others (Table I). In living organisms, fat is the usually stored form of energy. They are the main structural element of phospholipids and sterols (Hashim *et al.* 2014). The CF and crude carbohydrate (CC) contents showed the maximum value for flax genotype Canada (55.32%) and Nila (38.25%), respectively and a minimum for hemp genotype Brammonbaria (26.51%) and Meherpur (23.86%). The energy value of hemp genotypes was higher and ranged from

**Table I. Proximate analysis of fibres of different hemp and flax genotypes**

| Genotype | Dry matter (%) | Ash (%) | Crude Protein (%) | Crude Fibre (%) | Ether Extract (%) | Crude Carbohydrate (%) | Energy Value (kcal 100$^{-1}$ g) |
|---|---|---|---|---|---|---|---|
| Hemp | | | | | | | |
| Meherpur | 96.9 | 17.7 | 7.94 | 29.10 | 18.30 | 23.86 | 350.1 |
| Brammonbaria | 97.1 | 14.8 | 8.65 | 26.51 | 12.35 | 34.79 | 337.93 |
| Chittagang | 97.0 | 12.5 | 9.02 | 29.27 | 20.90 | 25.31 | 383.96 |
| Average | 97±0.08 | 15±2.13 | 8.54±0.45 | 28.29±1.26 | 17.18±3.58 | 27.99±4.85 | 357.33±19.47 |
| Flax | | | | | | | |
| Nila | 96.0 | 2.3 | 3.64 | 49.21 | 2.60 | 38.25 | 289.38 |
| Chilmari | 96.2 | 1.7 | 3.27 | 52.21 | 3.91 | 35.11 | 293.13 |
| China | 96.5 | 3.8 | 3.62 | 51.73 | 3.42 | 33.93 | 284.44 |
| BD-10708 | 96.8 | 1.8 | 5.24 | 47.28 | 9.70 | 32.78 | 333.94 |
| Canada | 96.7 | 1.8 | 3.98 | 55.32 | 4.50 | 31.1 | 291.46 |
| BD-1903 | 96.3 | 2.0 | 3.27 | 51.60 | 10.30 | 29.13 | 325.5 |
| Average | 96.4±0.31 | 2.23±0.79 | 3.84±0.74 | 51.23±2.75 | 5.74±3.36 | 33.38±3.18 | 302.98±21.09 |

337.93 to 383.96 kcal $100^{-1}$ g (Table I). This augmented energy value is due to their greater fat content compared with flax genotypes (Ishag *et al.* 2019).

Among the different plant parts of hemp, the leaf possessed the maximum amount (23.78%) of CP (Audu *et al.* 2014). On the other hand, fibre contains the highest amount of CF (28.29%) and ash (12%); EE (%) of the leaf was identical to that of fibre except in one genotype Brammonbaria (Table I) (Audu *et al.* 2014). In flax plants, seeds contain the highest amount of CP (21%) and EE (43.17%), and maximum CF (avg. 51.23%) and CC (avg. 33.38%) in fibre (Table I) (Ishag *et al.* 2019).

*Thermogravimetric analysis*

The TGA curves were used to determine the thermal behaviour such as weight loss and residual char level of material at a certain temperature. The thermal behaviour of untreated hemp and flax fibres is shown in Fig. 1. Fibres of all the genot ypea are lignocellulosic and show almost similar thermal degradation patterns. Thermal degradation profiles of the fibres are separated into three different stages. The first stage of degradation started at around 100°C and last up to 180°C. At this stage, about 10% mass loss occurs. Mass loss of fibres at around 100°C due to elimination or rapid evaporation of water during the initial stages of heating (Ouajai and Shanks, 2005). In addition to moisture, some fraction of waxes, pectin, lignin and hemicellulose degraded in this stage (Wielage *et al.* 1999). Decomposing of both the hemp and flax fibres takes place slowly up to about 250°C. Later the second decomposition started where the maximum mass loss occurred. Maximum decomposition took place between 250 and 350°C due to the depolymerization of cellulose and hemicellulose (Albano *et al.* 1999). It is obvious from the proximate analysis (Table I) that there is a difference in the chemical composition of the genotypes that affects the thermal stability. The thermal stability of the flax genotypes Chilmari and BD-10708 showed higher than the others. The third stage of decomposition begins at a temperature of about 350°C. At this stage, the fibre breaks down to form chars releasing water and carbon dioxide. With a further increase in temperature, the process of formation and digestion of chars takes place. The stable residual mass at 500°C temperature comes mostly from minerals and char residue (Gashti *et al.* 2013). Proximate analysis showed that hemp fibre had higher ash content on average than flax fibre (Table I). The TGA analysis also coincides with the proximate analysis showing a higher residual mass fraction at 500°C for hemp fibres.

**Conclusion**

The lower ash and ether extract and higher DM, CC and CF of these flax fibres make them (also) suitable for being used in the lightweight composite, textile, pulp and cellulose-based industries. The hemp fibre had higher ash which was reflected by a higher residue at 500°C in TGA analysis. High ash content in the hemp fibres will provide

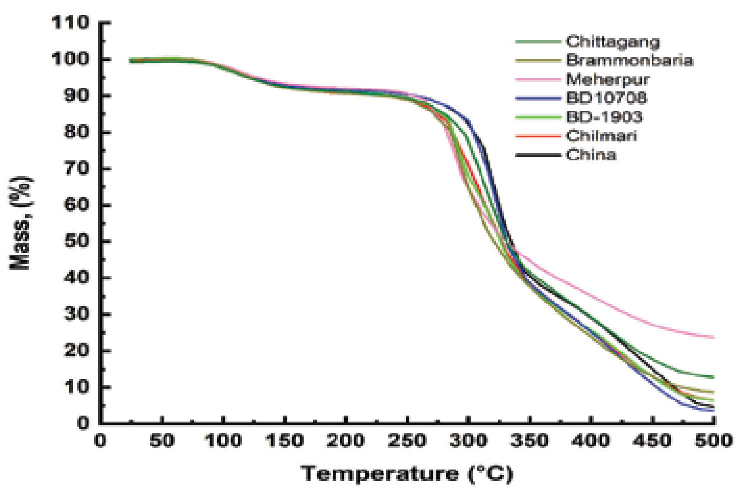


**Fig. 1. Thermogravimetric analysis curves of fibres of different hemp and flax genotypes**

high thermal stability and could be used as reinforcement material for composite. Further investigations are needed to understand the viability of these flax fibres for different purposes.

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