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Potential of bioenergy production from industrial kenaf (*Hibiscus cannabinus* L.) based on Malaysian perspective

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ABSTRACT

Nowadays, the energy requirement of increasing population is creating energy crisis, and it's become a serious and alarming thread for sustainability of natural resources. Moreover, upcoming demand of energy requirement is growing faster in developing countries as compared to developed ones. Malaysia is one of the fastest growing, developing countries, which is experiencing drastic and regular growth in population and economy in the recent years. It is an urgent requirement for the government and policy makers to explore alternative energy sources to accomplish upcoming demands of a growing population in the form of energy sufficiency. Malaysia is blessed with tropical and sub-tropical climates, which are suitable for exploring the green agriculture and forest potential. Most of the available energy resources in the form of fossil fuels have already been explored, and it is expected that energy demand will grow continuously by two to three fold in the next decades. Biomass resource is abundant in Malaysia. This can be considered as an alternative source of renewable and sustainable energy, with a promising future to fulfil continuous and uninterrupted supply of energy. Agricultural biomass such as Industrial Kenaf (*Hibiscus cannabinus* L.) has been successfully investigated as a great potential to be used as a renewable and sustainable feedstock for the production of bio-energy. Kenaf regarded as a traditional crop of Malaysia. Kenaf biomass would appear as a potential material for great sustainable energy (bioethanol, biohydrogen, bioenergy) supplier in the coming future. In this review, we have provided an insight of kenaf biomass, its morphology, structure, chemical compositions, storage and sowing, cultivation, harvesting, yield and different sustainable energy possible to get from it. We also discuss the feasibility of kenaf biomass as a sustainable energy source supplier in Malaysian prospective.

Contents

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1. Introduction

The majority of the world's energy is provided by the petrochemical sources, coal and natural gases, all of these energy sources are finite. These sources going to be consumed shortly in the incoming years due to over exploitations and the growing human population [1]. Energy needs and their demands are greatly expected to get multiple within the decade. All these create a serious problem towards the country's economy and raised the concerns about an insecure energy sources and their supply in the near future. Greenhouse gases released by fossil fuels are primarily responsible for the Global warming beside the risk of getting depleted in future [2]. Hence, it assumed that fossil fuels are not the reliable and faithful source of energy due to its non-renewable nature and going to scarce in coming [3]. Shortage of energy resources and environmental pollutions are two major challenges which can be solved by finding alternative sources of renewable and sustainable, the biomass energy resources.

Currently, biofuels emerged as a sustainable alternative source of energy to replace conventional fossil fuels. Biogas, biohydrogen, bioethanol and biodiesel can be obtained using biomass as a feedstock. Grain, seeds, stems, husks from a large variety of crops like wheat, rice, soyabean, etc. are used to produce biofuels. Lignocellulosic biomass (LCB) are one of the most abundant bioresources in the world, with an annual world growth of 170–200 billion tons [3]. LCB is preferred as a feedstock for bioenergy production. Among the LCBs only those are preferred that achieve higher yield per hectare. Yield of energy crops depends on soil and their fertility, like it should sustain by adopting crop rotation [1]. Bioenergy feedstocks are those that can favour in maintaining the soil fertility through crop rotation. As the feedstock cost affects the cost and the economics of biofuel production and it depends on the cultivation of biomass [4].

Kenaf term originated from Persian word which explain the plant of warm season, short day and herbaceous annually [5]. Kenaf is an important textile fibre in southeast Asia and other tropical countries [6]. Industrial kenaf regarded as the traditional crop of Malaysia, along with other developing countries after wood and bamboo as an annual resource of energy for the industrial purpose kenaf is first introduced in the early of 1970 [7]. They are mostly found in temperate and tropical regions. Like okra, hibiscus, jute and cotton kenaf possess the same systematic nomenclature and has been cultivated in its native Africa since 4000 BC [8]. Currently, many countries pay more attention to kenaf research and promotion because of its high biological efficiency and wide ecological adaptability.

Kenaf regarded as the alternative and cheaper source of energy which possess high growth rate and ready for harvesting in 4–5 months and consist of a core (65%) and bast fibres (35%) [7]. Industrial kenaf is usually cultivated to obtain fibres and the high protein animal feed [7]. The long bast fibres are being used to produce high grade pulp for the pulp paper industry, protective packaging for fruits and vegetables, composite board and textiles and the filters [9–11]. Kenaf posses several features which are responsible to consider it as an ultimate choice for biomass and bioenergy production kenaf possess low feedstock, high biomass content, and negligible pesticide requirement along with low crop rotation. Kenaf possess negligible environmental impacts comparing to other lignocellulosic feedstocks grown for biofuel production [3]. Kenaf produces negligible environmental effects, however, the application of organic fertilizer in combination with chemical fertilizer (NPK), had significant effects on the growth of kenaf without much impact on the environment [12].

To the best of our knowledge, so far there is no any significant work has been done in this area. In the prospective of the ever increasing demand of the fossil fuels and the future vision, the kenaf would emerge as an alternative source of energy producer. In this review, we try to explore properties of industrial kenaf to project it as a prospective energy crop in the Malaysia which could be an alternative source of future energy and fulfil current and future energy demands of a growing population.

2. Botany, structure and composition

Industrial kenaf is a dicotyledons plant, belonging to the genus Hibiscus and family Malvaceae. It is an annual or biennial herbaceous (rarely a short-lived perennial), short day plant, growing to 1.5–3.5 m tall with a woody base. The stems are 1–2 cm diameter, often but not always branched. The leaves are 10–15 cm long, variable in shape, with leaves near the base of the stems being deeply lobed with 3–7 lobes, while leaves near the top of the stem are shallowly lobed or unlobed lanceolate. The flowers are 8–15 cm diameter, white, yellow, or purple; when white or yellow, the centre is still dark purple. The fruit is a capsule 2 cm diameter, containing several seeds.

Kenaf stem consists of two parts, outer part known as bast fibres and inner part—core fibres [13]. Central part of is known as pith mainly consists of the polygonal parenchymatous cells [14]. The bast fibres possess characteristic mechanical properties, making its suitable reinforcing materials to replace glass fibres as reinforcing materials in polymer composites [15–17]. The bark and core of kenaf can be distinguished by chemical composition

Table 1
Chemical composition of different fractions of kenaf fibres [7].

	Kenaf whole (core + bast)	Kenaf core	Kenaf bast	Softwood	Hardwood
Extractive (%)	6.4	4.7	5.5	0.2–8.5	0.1–7.7
Holocellulose (%)	87.7	87.2	86.8	60–80	71–89
α-Cellulose (%)	53.8	49.0	55.0	30–60	31–64
Lignin (%)	21.2	19.2	14.7	21–37	14–34
Ash (%)	4.0	1.9	5.4	< 1	< 1