Europ. J. Agronomy 60 (2014) 1–12

Contents lists available at ScienceDirect

European Journal of Agronomy

journal homepage: www.elsevier.com/locate/eja

Energy crops: Prospects in the context of sustainable agriculture

Luis López-Bellido[a,*], Jacques Wery[b], Rafael J. López-Bellido[a]

[a] Departamento de Ciencias y Recursos Agrícolas y Forestales, University of Córdoba, Campus de Rabanales, Edificio C-4 "Celestino Mutis", Ctra. Madrid km 396, 14071 Córdoba, Spain
[b] Montpellier Sup Agro UMR System 2 place Viala, 34060 Montpellier, France

ARTICLE INFO

Article history:
Received 12 June 2013
Received in revised form 2 July 2014
Accepted 5 July 2014
Available online 26 July 2014

Keywords:
Biomass
Energy crops
Biofuel
Biorefinery
Environment

ABSTRACT

The objectives of this review are to analyse the potential of bioenergy crops development in European agriculture and to identify research objectives based on transformation technologies. Bioenergy is the chemical energy stored in organic material, which can be directly converted into useful energy sources by biological, mechanical or thermochemical processes. The substitution of food crops with energy crops and the demand for agricultural raw materials for liquid biofuel production will affect agriculture over the next decade and possibly beyond. It is expected that both second-generation biofuel production technology and energy crops used will be more efficient than first-generation. Nonetheless, there are still technical limitations for crop growth and fuel production from second-generation technology. In general, many of the crops that could supply the raw materials for second-generation biofuels are largely undomesticated and are in the first stages of development and management. The development of specific crops dedicated to energy has been proposed as a strategy to produce energy without affecting food security and the environment. The research seeks to develop enzymatic systems for the cost-efficient decomposition of cellulose into its molecular sugar components, which can then be fermented to produce ethanol. This biorefinery of crops into multiple products, including energy, chemical products and materials, will augment the overall value of the biomass. Clearly, multidisciplinary research is necessary to address sustainable biofuel production.

Contents

* Corresponding author. Tel.: +34 957 218495.
E-mail address: cr1lobel@uco.es (L. López-Bellido).

http://dx.doi.org/10.1016/j.eja.2014.07.001
1161-0301/

1. Introduction

The importance of energy transcends economic limits. It is the belief that access to energy supplies is as basic a service as sanitation and education and is an inherent right of citizens; hence, the guaranteed supply of energy is demanded of governments. However, external economic factors that affect the extraction, handling and distribution of goods and services have an environmental impact on natural resources and waste and have led society to be wary of the environmental implications of available energy supply models. The influence of the energy sector on society compels government mandates to define an energy policy that can respond to society's demands (Becker, 2011).

In the developed world, fossil fuels have provided between 85 and 93% of the world's energy requirements for the past 50 years. The concept of peak oil extraction is now widely accepted. According to some experts, the peak in oil production may occur in 20 years, whereas others argue that the world has already reached its peak production. Beyond the concept of peak oil production, a production profile also exists that is equally difficult to predict. In summary, data on the remaining oil reserves and their depletion rates are uncertain, which makes accurate predictions difficult and may depend on the prediction methods used (Black et al., 2011). Currently, it is generally accepted that this peak will occur soon and that an energy transition is inevitable. The exact cost, as well as the discovery and exploitation of new oil resources in the coming decades, is uncertain; however, the cost will certainly be substantial. The investment required to finance these activities is one of the major challenges for future energy supplies (Bessou et al., 2011; Hughes and Rudolph, 2011).

Based on these predictions, it is evident that alternatives to fossil fuels (and fossil raw materials for the chemical industry) are necessary. Many countries have searched for renewable energy options, such as wind, solar, tidal and bioenergy sources. Biofuels currently represent the only supply option for renewable liquid fuels for both internal combustion and reaction engines (Black et al., 2011).

According to Bessou et al. (2011), the dependence of the European Union (EU) on energy imports could reach 70% of its overall energy needs by 2030. Currently, the dependence level has already reached 50%, and the energy demand has increased steadily by 1–2% annually since 1986. This increased supply and the environmental costs of oil activities have pushed petroleum out of its exclusive candidacy as the universal energy source, allowing other energy sources to be more competitive. Nonetheless, no alternative energy source is interminable, and the long drawn-out complacency of energy companies for developing clean energy alternatives has hindered progress in this field. There is no other solution but to diversify combinations of energy sources with increasing contributions from clean energy alternatives.

Bioenergy is the chemical energy stored in organic material, which can be directly converted into useful energy sources by biological, mechanical or thermochemical processes (Bessou et al., 2011). The term bioenergy refers to the renewable energy from biological sources that can be used for heating, electricity and fuel as well as their by-products. Regarding modern bioenergy, ethanol, biodiesels and biogas are the three main bioenergetic products (Yuan et al., 2008). Bioenergy has been promoted as a fossil energy substitute to reduce greenhouse gas (GHG) emissions and the dependence on energy imports (Haberl et al., 2010).

The term "biofuel" is used to describe the intermediate products in the biomass energy chain that are obtained from raw materials, through their pre-treatment or conditioning by physical, thermochemical, chemical or biologic processes. Depending on their nature, it is worth distinguishing among solid, liquid and gaseous biofuels. Generally, biofuels used in the transportation sector are currently represented mainly by liquid bioethanol and biodiesel. In contrast, biogas that is obtained by the anaerobic treatment of organic waste is currently the main gaseous biofuel (Antizar-Ladislao and Turrión-Gómez, 2008).

Bioenergy offers the advantage of generally low-level investments. In addition, the diversity of raw materials and the transformation processes offer a broad range of possibilities that can be adapted to different geographical regions, environments and needs (Bessou et al., 2011). According to Winslow and Ortiz (2010), there are five crucial aspects of bioenergy production: (i) energy security, (ii) food security and rural development, (iii) environmental impact, (iv) technical innovation, and (v) political and institutional roles. However, the main factor that will limit biofuel development will be land availability (Bessou et al., 2011) if we want to avoid the reduction of food production.

The objectives of this review are to analyse the potential of bioenergy crops development in European agriculture and to identify research objectives based on transformation technologies. Clearly, it requires multidisciplinary research to address sustainable biofuel production.

2. Economics of bioenergy production

The total global demand for primary energy reaches approximately 11.4 billion tonnes of oil equivalent (Gtoe) each year (IEA, 2007); biomass, including agricultural and forest products as well as organic waste and residues, comprises 10% of the total (Fig. 1). Liquid biofuels play a more limited role in the global energy supply and comprise only 1.9% of the total bioenergetics. The importance of liquid biofuels lies mainly in the transportation sector. In recent years, however, liquid biofuels have seen a rapid rise in terms of volume and contribution to the transportation-related global energy demand. This growth is expected to continue, as shown in Fig. 2, which depicts the historical trends as well as projections for 2015 and 2030, according to the report by the World Energy Outlook 2007 report (IEA, 2007). Nonetheless, the contribution of liquid biofuels to transportation energy and global energy use will remain limited (FAO, 2008).

Generally speaking, the recent increase in biofuel production has occurred in countries that are members of the Organisation for Economic Co-operation and Development (OECD), mainly the United States of America and members of the EU. The exception is Brazil, which is the first country to develop an economically

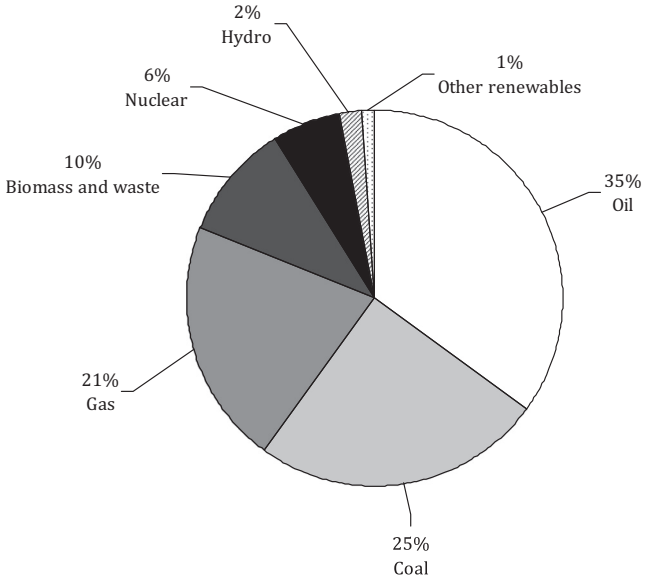

Fig. 1. World primary energy demand by source (adapted from FAO, 2008).