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Review

The prospects of Jerusalem artichoke in functional food ingredients and bioenergy production

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ABSTRACT

Jerusalem artichoke, a native plant to North America has recently been recognized as a promising biomass for bioeconomy development, with a number of advantages over conventional crops such as low input cultivation, high crop yield, wide adaptation to climatic and soil conditions and strong resistance to pests and plant diseases. A variety of bioproducts can be derived from Jerusalem artichoke, including inulin, fructose, natural fungicides, antioxidant and bioethanol. This paper provides an overview of the cultivation of Jerusalem artichoke, derivation of bioproducts and applicable production technologies, with an expectation to draw more attention on this valuable crop for its applications as biofuel, functional food and bioactive ingredient sources.

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1. Introduction

Since the beginning of the 21st century, civilization has been facing two major problems: the steady decline of fossil fuels, and environmental problems caused by the extensive use of these fossil fuels for the production of energy and chemicals. One effective way to address these challenges is to use biomass instead of fossil fuels

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for the production of fuels and chemicals, an emerging area termed as "bioeconomy". This type of economy undoubtedly contributes to environmental, social and economic sustainability if it is well designed and implemented [1–3]. A critical aspect of shifting from the current "petroeconomy" to a "bioeconomy" is to minimize the impact of new applications of biomass (i.e., fuels and chemicals) on traditional uses of biomass (i.e., food and feed), thereby preventing any resultant economic imbalance. Therefore, significant academic and industrial activities are focused on identifying abundant biomass sources and/or developing crops that are less competitive with conventional crops in terms of water, land and nutrient requirements. The availability and application of biomass sources are region-dependent and it is therefore essential to identify plant species suitable to local cultivation conditions to increase the economic viability of biomass production [4–6]. Two commonly cited examples of successful transition to a bioeconomy include bioethanol production from sugarcane in Brazil and biodiesel production from non-edible *Jatropha* oil in South Asia; however, these species cannot be applied readily to North America without considering the degree of climatic adaptation [7–9].

Jerusalem artichoke is a plant native to North America. It has a number of advantageous characteristics over traditionally agricultural crops, including high growth rate, good tolerance to frost, drought and poor soil, strong resistance to pests and plant diseases, with minimal to zero fertilizer requirements [10,11]. Conventionally, Jerusalem artichoke has been used for food or animal feed [12,13], and for the past two decades, alternative uses have been explored especially for the production of functional food ingredients such as inulin, oligofructose and fructose [14,15]. It is also found that some bioactive ingredients can be extracted from its leaves and stems, which creates an opportunity for applications in the pharmaceutical sector [16,17]. More recently, a renewed and rapidly growing interest is for the use of Jerusalem artichoke tubers, which are rich in inulin, as raw materials for bioethanol production [18,19]. Multiple applications of Jerusalem artichoke are illustrated in Fig. 1. These diverse applications along with low-cost of plantation render Jerusalem artichoke a promising biomass for the development of a bioeconomy.

This review is a comprehensive survey of the cultivation of Jerusalem artichoke, production of a variety of potential bio-products and applicable production technologies. Considerable emphasis is placed on Jerusalem artichoke bioethanol production.

2. Characteristics of Jerusalem artichoke

Jerusalem artichoke (*Helianthus tuberosus*) is a perennial plant which consists of a stem about 1–3 m tall, small yellow flowers, hairy oval shaped leaves and an underground rhizome system which bears small tubers. It is an Angiosperm plant species of the Compositae family, which is commonly referred to as the sunflower or daisy family [10,20–22]. The stems are stout and ridged which can become woody overtime. Its leaves alternate near the top of the stem, the lower leaves are larger and broader, and can grow up to 30 cm long while the higher ones are smaller and narrower. In terms of flower heads, each is 5–7.5 cm wide and formed by small, yellow, tubular disk flowers in the center and surrounded by florets, which occur separately or in groups at the end of alar branches and main stems. As for tubers, they are uneven and elongate varying from knobby to round clusters. The colors of tubers range from pale brown to white, red and purple [10,23]. The morphology of Jerusalem artichoke plant and tubers are illustrated in Fig. 2.

The Jerusalem artichoke was first cultivated by Native Americans long before the arrival of the Europeans, and was called sunroots. Following its introduction to Europe, diverse Latin and common names were ascribed to Jerusalem artichoke. Kays and Nottingham [22] collected and reported nearly 100 common names used in different languages. Now some of the most commonly used English names include Jerusalem artichoke, sunchoke, topinambur, woodland sunflower or earth apple. Interestingly, the name "Jerusalem artichoke" is misleading as it is a type of sunflower in the same genus as the garden sunflower; however, it has no relation to Jerusalem, neither is it a type of artichoke [24].

3. Cultivation of Jerusalem artichoke

Jerusalem artichoke is native to temperate regions of North America and can tolerate an annual precipitation ranging from 31 to 282 cm, with suitable average temperature range of 6.3–26.6 °C, and pH of 4.5–8.2. Although it can adapt well to a wide range of soil types and pH levels in a sunny position, slightly alkaline soils are favorable for artichoke production. Generally the plant can tolerate sub-zero temperatures while the tubers can withstand freezing for several months even if the frost kills the stems and leaves. The cold-tolerant nature of the tubers allows them to be preserved in the ground during the cold winter until harvested as required [10,22].

Several studies suggested that Jerusalem artichoke should be planted in early spring to a depth of 10–15 cm. Seed tubers should be spaced 30–60 cm apart in each row, with rows 45–120 cm apart. The optimal soil temperature for planting is between 6 and 7 °C due to the fact that tubers become dormant at temperatures lower than 5 °C. Ideally, it should be planted in well-drained soil with

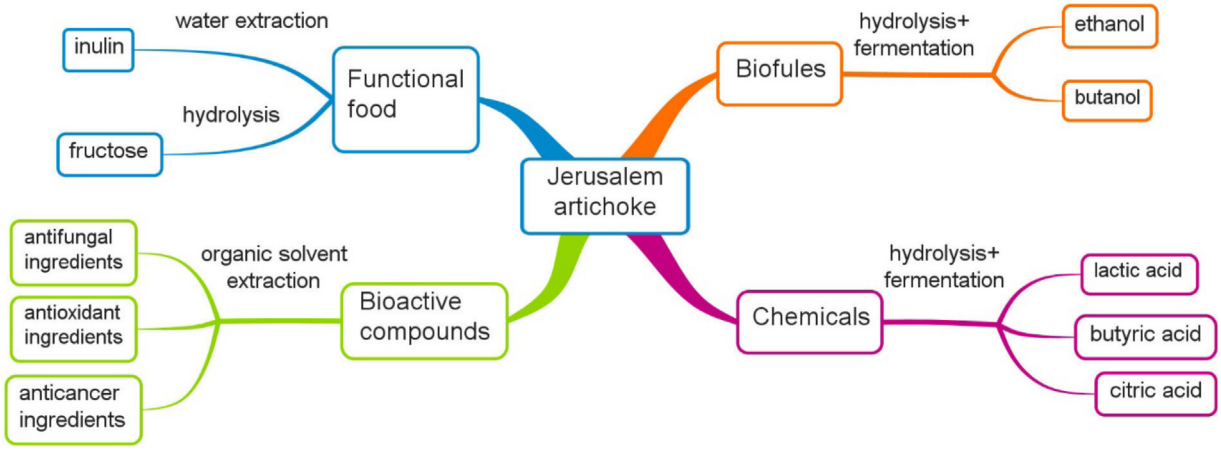

Fig. 1. Multiple applications of Jerusalem artichoke.