Taraxacum kok-saghyz (TK): Compositional Analysis of a Feedstock for Natural Rubber and other Bioproducts

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ABSTRACT

Natural rubber (NR) is a critical raw material primarily produced in Asia from a single plant species (*Hevea brasiliensis*). This lack of biologic and geographic diversity, coupled with increasing demand, makes it imperative that alternative sources of NR are developed. *Taraxacum kok-saghyz* (TK) is a rubber-producing dandelion being developed as an alternative to the traditional source of NR. The composition of TK roots and potential co-products that could be produced from this crop are understudied. Therefore, a compositional analysis of field harvested TK roots was conducted to identify components of the roots that may have commercial value and inform the design and development of processes for the recovery of NR and other valuable coproducts from TK roots. Field-grown TK roots were analyzed by wet chemistry methods to identify and quantify TK components. Mass closure was greater than 95%. The analysis showed that water-, acetone-, hexane-extractable (rubber) fractions represented 60%, 1.7%, and 5.4% (root dw basis). Soluble sugars (32%) and proteins (10%) were the most abundant water soluble components. Insoluble components included cellulose 9%, hemicellulose 7%, lignin 5%, protein 5% and pectin 3%. This compositional analysis provides a baseline which can be used to assess compositional changes induced by altering plant genetics, environmental conditions, and cultivation practices. Based on these results, pathways for TK processing are proposed, and its potential as a biorefinery feedstock is evaluated. This analysis indicates that TK has potential as a source of not only NR but other products and/or raw materials of importance including inulin and proteins.

INTRODUCTION

NR is an essential raw material used throughout the world. In 2014, the US imported 9.6x10^8 kg of NR at a total cost of US$2 billion (1). Currently there is no NR produced domestically for commercial purposes and nearly 100% of it is produced in Asia from a single plant species (1). This lack of biological and geographical diversity, coupled with burgeoning demand, makes it imperative that alternative domestic rubber sources are developed. Ohio, the center of the US rubber industry, has addressed this need through the creation of an academic/industry consortium called PENRA led by OARDC. The goal of PENRA is to develop a rubber-producing dandelion, TK, as a commercial viable alternative source of NR. One of the major challenges to the development of an economical supply of NR from TK roots is the large quantity of byproducts that result from separating and purifying its NR. These non-rubber components of the roots can be used directly or transformed into bioproducts of value to various commercial sectors. Thus, any techno-economic analysis of the use of TK as a source of NR should also consider its overall composition. In order to assess TK as a potential biorefinery feedstock, the objectives of this study were to: 1. Conduct a comprehensive chemical compositional characterization of field grown TK roots; 2. To estimate the value of potential products made from TK roots.

RESULTS

Figure 1. Overall composition of field-grown TK roots

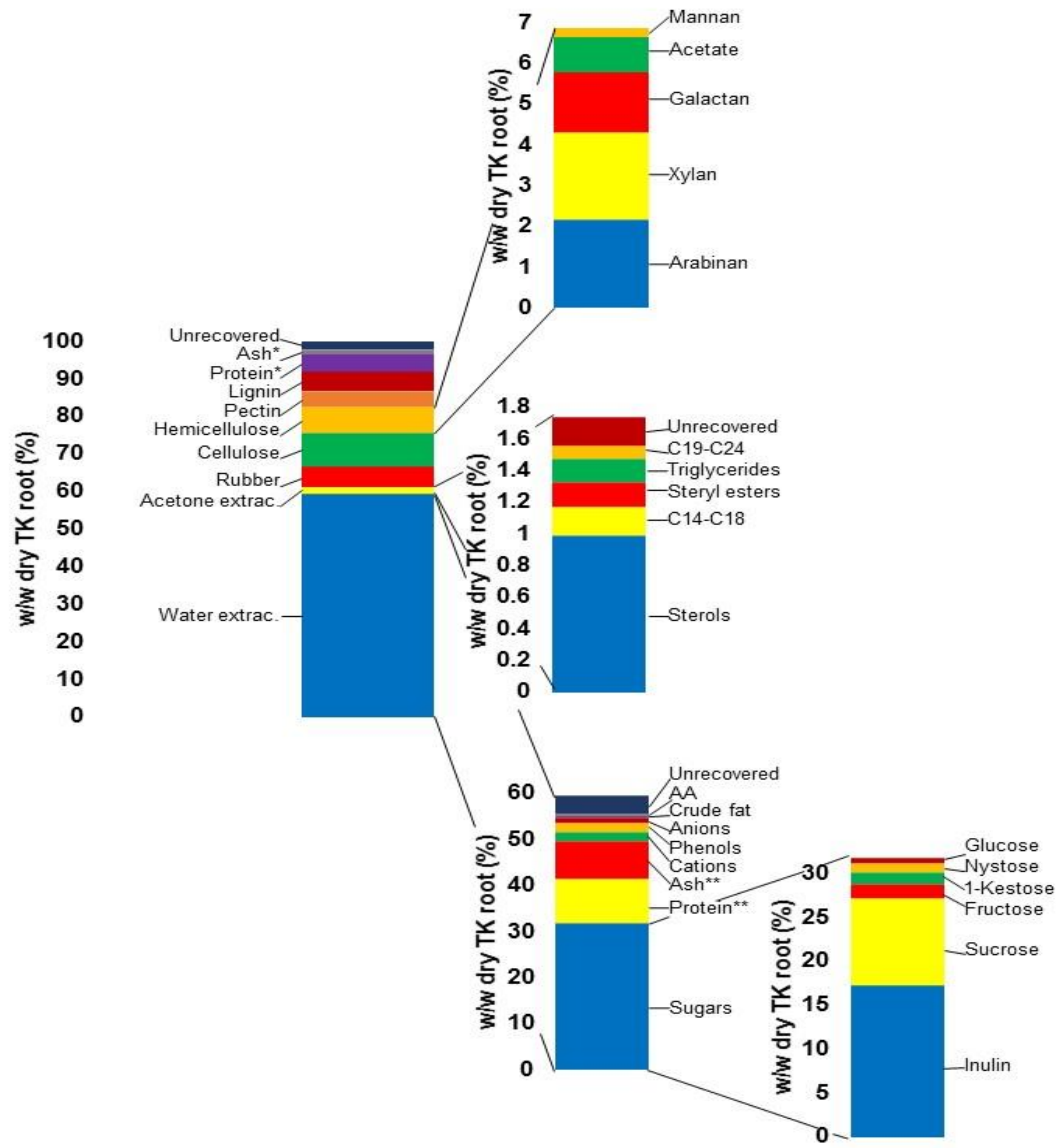

Table 1. Potential yields of NR and other bioproducts from TK roots within a biorefinery context

Potential biobased chemical	Production	Units	Yield	Source
Rubber	389	kg/ha	1.0	Hexane extractives
Inulin	1248	kg/ha	1.0	Inulin
Protein	702	kg/ha	1.0	Water soluble protein
Arginine	202	kg/ha	1.0	Water soluble protein
Aspartic acid	149	kg/ha	1.0	Water soluble protein
Glutamic acid	99	kg/ha	1.0	Water soluble protein
Proline	114	kg/ha	1.0	Water soluble protein
Fructose and glucose	1051	kg/ha	1.0	Water soluble oligo- and mono-saccharides
Cellulose	647	kg/ha	1.0	Lignocellulosic fraction
Hemicellulose	496	kg/ha	1.0	Lignocellulosic fraction
Ethanol	1372	kg/ha	0.738and 0.721	Cellulose and hemicellulose
Ethanol	612	kg/ha	0.49	Inulin
2,3-Butandiol	603	kg/ha	0.48	Inulin
Succinic acid	746	kg/ha	0.71	Fructose and glucose
Acetone butanol ethanol	758	kg/ha	0.33	Water soluble sugars (inulin not included)

MATERIALS AND METHODS

A representative sample of 3 kg of dry TK roots harvested from field plantings in Ohio was used to generate a reference compositional analysis. NREL protocols for biomass compositional analysis (2) were used to identify and quantify components in the whole TK roots.

DISCUSSION

Chemical characterization of TK root components through compositional analysis is an important first step in determining the potential for the valorization of TK roots. A highlight of this analysis is its ability to estimate the potential of TK roots as a biorefinery feedstock and estimate yields of potential products from TK roots, including rubber, inulin, and protein. Based on the characterization of TK roots, potential yields of various biobased products were calculated (Table 1). TK field trials conducted at OARDC/OSU Wooster, Ohio showed that 1.2 million TK plants can be planted per hectare without self-thinning and that the mean dry weight root per plant was approximately 6 g. Using these values, the theoretical yields of TK compounds per hectare were estimated.

While none of the individual TK product yields exceed those of commercial sources, taken together the value of TK products may generate a crop value higher than that of other crops. Results presented in Table 1 are for an estimated production level, and actual production levels could be affected by variables such as plant growing conditions, process parameters, and economic factors. Further development of a biorefinery approach for TK roots would benefit from an appropriate techno-economic analysis to assess its feasibility.

CONCLUSIONS

The TK root compositional analysis provides a foundation upon which future work on breeding, germplasm development, seasons and cultivation practices can be evaluated.

The biorefinery proposed from the analysis has the following operations: inulin and proteins are water extracted, NR is released after chemical pretreatment and enzymatic hydrolysis of extracted roots and sugars are fermented to chemicals and/or biofuels.

These results indicate that TK could be an economical biorefinery feedstock for the production of NR, inulin, protein, chemicals and biofuels. These results provide valuable data for the development of techno economic models for alternative natural rubber production from TK.

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