

TOBACCO BIOMASS AS SOURCE OF BIO-BASED MATERIALS¹

Marija Srbinoska, Professor
Valentina Pelivanoska, Professor
Vesna Krsteska, Professor
Biljana Jordanoska Shishkoska, Associate professor
University St. Kliment Ohridski –Bitola
Scientific tobacco institute-Prilep, Kicevska nn 7500 Prilep
e-mail: marija.srbinoska@uklo.edu.mk

ABSTRACT

Tobacco is widely cultivated as an important nonfood economic crop throughout the world, and large amounts of biomass are generated during the vegetation and post-harvest processes. Biomass has a complex composition, including large amounts of sugars, proteins and oil can be used to produce animal feed, as well as lignin and hemicellulose for energy.

This study is conducted with the focus on the application of biotechnology for the production of biomass-based materials from tobacco through research and literature review. The study focused on three objectives, examining the potency of tobacco seeds and stalks, obtaining and handling raw materials and their application.

Leaves contain about 1–4 % fatty acids per dry weight, and seeds contain about 40 % oil, which makes them good sources for biofuel. Because of the high contents of lignin (40–45 %) and cellulose (28–40 %), tobacco stalks can be used for production of briquettes, pellets, and ethanol.

KEY WORDS: biomass, tobacco, leaves, stalk, lignin

INTRODUCTION

Tobacco is an industrial crop conventionally used for manufacturing different type of tobacco products. The crop is currently cultivated in

¹ original scientific paper

approximately 130 countries, in area covering almost 3.4 million hectares, with more than 6 million tons yield harvested each year (FAOSTAT, 2020).

The chemical properties of tobacco plant are influenced by the genetics, agriculture practices, soil type and nutrients, weather conditions, plant disease, harvesting and processing (Leffingwell, 1999).

Tobacco has a complex chemical structure that comprises more than 3,000 compounds, making it suitable for biogenic and transgenic research (Rodgman, 2013).

Tobacco requires minimal resources (water and fertilizer) and can be grown on marginal lands, or those which are not suitable for food crops. Today biomass crops suitable for cultivation on marginal lands raise attraction, as they could supply biomass without competing for land with food supply (Berbec, 2020; Pancaldi, 2020).

Also, there are several advantages that tobacco offers from a growing and harvesting perspective. The plant has a fast-growing cycle, some types allowing for more than one harvest per season, and farmers are able to process it fresh without the need for drying. In this context, tobacco has a higher concentration of usable biomass than any other agricultural crop, making it an efficient crop for bio-based industries.

Tobacco stalks are the biomass waste after tobacco harvesting. The yield of stalks in tobacco production is around 20% (Yang et al. 2012), far more than any other tobacco residues (tobacco stems, tobacco debris, et al.). The literature findings showed that stalks and other tobacco residues could be used in various products, in the production of pulp and paper, briquettes, bio-fuel, bio-ethanol, as well as, inorganic fertilizer (Sun and Cheng, 2002; Chaturvedi et al., 2008; Peševsk et al. 2010; Shakhes et al., 2011). Therefore, great economic benefits can be achieved by appropriate utilization of this biomass. From the existing literature, reported works on physico-chemical properties and lignocelulosic composition of tobacco residues are insufficient. Due to the rich complex carbohydrates, wide availability, and low cost, tobacco stalk could also be used for biofuel production (Cai et al., 2016). Maisashvili et al. 2016 has been shown that tobacco-based renewable fuel production can become economically viable.

Tobacco seed as a secondary product of tobacco leaf production contains oil in a wide range of 32- 41% of the seed weight depending on a number of factors including the variety, agroclimatic and soil conditions (Mukhtar, 2006). Recently, tobacco seed lipid had been demonstrated to be a promising feedstock for biodiesel production (Veljkovic et al., 2006; Banković-Ilić et al., 2012; Kumar and Sharma, 2016).

The objective of this study is to identify alternative use of tobacco as a sustainable crop for production of bio fuels. Currently, two main products can be produced from a tobacco plant if used as a feedstock, a tobacco stalks, and seed oil.

MATERIAL AND METHODS OF WORK

The objective of the study is to assess the usability of tobacco stalks and seeds for the production of high value bio-products. First, we independently analyse of both type of biomass. Following, we discuss major requirements for tobacco-based biofuel production to become financially feasible.

RESULTS AND DISCUSSION

Tobacco production in terms of area, yield and quantity

According to FAOSTAT, different types and varieties of tobacco are grown in approximately 130 countries and occupy significant areas for their cultivation. More than 40% of the world's tobacco is produced by China. All the largest producers are located outside the European Union (Table 1).

Table 1. Production, area harvested and average yield of tobacco in world

Area	Production (Thousands of Mg)	Area harvested (Thousands of ha)	Average Yield (Mg ha ⁻¹)
China	2242.2	1003.7	2.2
Brazil	762.3	356.5	2.1
India	749.9	417.7	1.8
USA	241.9	117.9	2.0
Indonesia	181.1	203.0	0.9
Pakistan	106.7	46.3	2.3
Malawi	95.4	86.1	1.1
Argentina	104.1	57.4	1.9
Zambia	115.9	65.7	1.8
Italy	59.3	17.2	3.4
Poland	33.2	16.4	2.0
European union countries	178.3	77.9	2.3
World (total)	6094.9	3368.9	1.8

Source: Food and Agriculture Organization Data (FAOSTAT) (2018)

Currently, at least 6 million tons of tobacco leaves are produced worldwide. It is estimated that about 60% of tobacco biomass is unsuitable for industry and is unnecessary waste. After harvesting, stalk of a height of approximately 2.5 m are left on the fields. Those wastes are most often burned or left on the field's surface.

Biomass for energy production refers to plant biomass that is composed of cellulose, hemicellulose, and lignin. Tobacco stalk is composed largely of cellulose, a polymer of glucose; hemicellulose, and lignin, a complex phenolic polymer (Shakhes et al. 2011). When managed properly, they can contribute to biogas, bioethanol, and biodiesel production.

Tobacco stalks as feedstock for biofuel production

Currently inn area covering almost 3.4 million hectares at 40 % moisture content, about 5 tons of tobacco stalks per hectare and year are produced only in six months duration (Table 1).

The morphological properties and chemical composition of stalks of tobacco type Burley were investigated to evaluate its usability (Srbinska, 2013).

The cellulose content was determined following the Kurshner-Hoffer method, and soluble lignin was determined by spectrophotometric measuring the absorbance of the hydrolysate at 205 nm wavelength.

Table 2. Chemical composition of the air dried (A) and field dried (F) tobacco stalks

	Cellulose		Total lignin		Acid insoluble lignin		Acid soluble lignin	
	A	F	A	F	A	F	A	F
Average value (%)	38.53	36.38	22.47	21.32	20.72	19.43	1.77	1.90
Standard deviation	0.12	0.15	0.16	0.12	0.12	0.15	0.05	0.06
Relative standard deviation (%)	0.31	0.40	0.73	0.55	0.56	0.77	2.92	3.33

From our investigation the chemical analysis of whole tobacco stalks, air and field dried stalks the cellulose was determined as major component, followed by acid insoluble lignin.

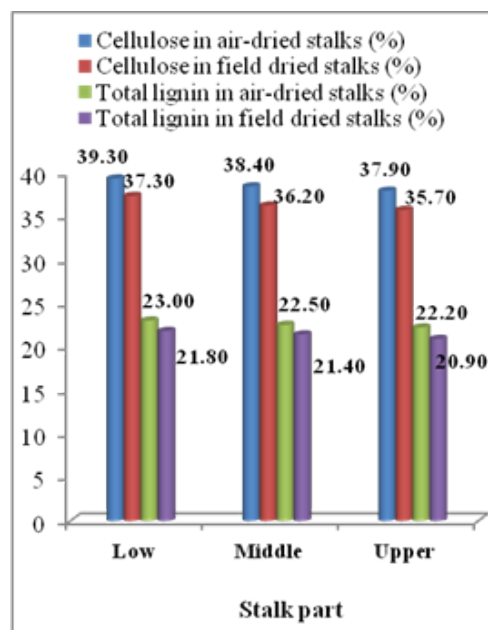


Figure 1. Cellulose and total lignin dynamics in relation to the stalk position

In terms of chemical composition (Figure1) of stalk position the lower part of the stalks contains higher cellulose and lignin than the middle and upper part which is expected since the latter is less mature, hence, less fibrous and less lignified.

Our results indicate that cellulose and lignin content in air-dried stalks are slightly higher, compared to those dried in field. Tobacco stalks possess high cellulose content and lignin and are considered desirable for use as feedstock for bio-based industries.

Tobacco seeds as feedstock for biofuel production

Tobacco seeds a by-product of leaf production contain oil in a wide range of 33- 40%, of total seed weight (Srbinska, 2009). The main fatty acids of tobacco seed oil are linoleic acid (66-76%), oleic acid, palmitic acid, and stearic acid (Veljković, 2006; Srbinska, 2009; Kirkova et al. 2016). Furthermore, the tobacco seed cake, which is an oil extraction by-product, turns out to be a suitable source of amino acids for animal feed formulations (Srbinska, 2005).

In our study successive tobacco seed oil extraction indicated that almost 38% of the seed was oil. The fatty acid methyl esters (FAMES) were prepared by boron trifluoride (BF₃) method. The FAMES were then analysed using a gas chromatography coupled with FID detector and with a fused silica capillary column-DB-23 (Srbinska, 2009).

Results for fatty acid composition of the studied tobacco seeds of oriental tobacco are presented in Figure 2.

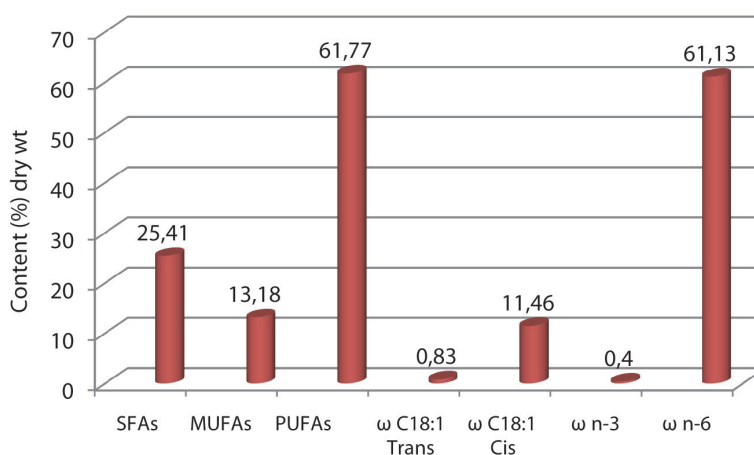


Figure 2. The fatty acid profile of seed oil from Oriental tobacco

The result showed that the oriental tobacco seed oil contains the highest percentage of long chain mono and polyunsaturated fatty acids: oleic acid (C18:1), linoleic acid (C18:2) and linolenic acid (C18:3). Ratio to monounsaturated fatty acids (MUFAs) to polyunsaturated fatty acids (PUFAs) governs the good stability of oil.

The chemical characterization of tobacco seeds has been found important to look at alternative products of the crop i.e. oil and seed cake and find some uses of these products. All these properties are comparable with properties of other vegetable oils which makes this oil a suitable initial raw material for the production of biodiesel fuel. However, tobacco yields a modest amount of about 600 kg of seeds per acre, significantly lower than the traditional biofuel oil producers, such as soybean or rapeseed.

CONCLUSION

Tobacco stalks as agricultural wastes from the harvesting of tobacco are useful biomass which can be used as feedstock in biotechnological processes. The chemical composition mainly complex carbohydrates have

potential for biofuel production. The utilization of this material for biofuel and ethanol production does not only solve the proper disposal of these wastes, but also provides an opportunity to use tobacco for unconventional purposes.

While oil content of tobacco seeds as biomass is much lower than that of oil-crop seeds, we believe that, because of its biomass potential and the possibilities of metabolic engineering, tobacco could also serve as a model for the utilization of other high-biomass plants for biofuel production.

Although the oil content of tobacco seeds as biomass is much lower than that of oilseeds, we believe that, due to its biomass potential and the possibilities of metabolic engineering, tobacco can also be included in non-food plants for biofuel production.

According our opinion, under the assumptions made in the study, using tobacco as a biofuel feedstock, regardless of its high biomass potential, is still in its early stages and require further technological and agronomic improvements before commercialization.

REFERENCE

1. FAOSTAT. Food and Agriculture Organization of the United Nations, Database on Crops Statistics. 2018. Available online: <http://www.fao.org/faostat/en/#data/QC> (accessed on 5 December 2020).
2. John.C. Leffingwell, Chapter 8. Leaf Chemistry in Tobacco: Production, Chemistry, And Technology, D. Layten Davis and Mark T. Nielson, Eds., Blackwell Science (Pub.), 1999.
3. Alan Rodgman, Thomas A. Perfetti, The Chemical Components of Tobacco and Tobacco Smoke, 2nd Edition, 2013.
4. Adam Kleofas Berbec, Mariusz Matyka, Biomass Characteristics and Energy Yields of Tobacco (*Nicotiana tabacum* L.) Cultivated in Eastern Poland, Agriculture, 10, 551, 2-12.
5. Francesco Pancaldi, Luisa M. Trindade, Marginal Lands to Grow Novel Bio-Based Crops: A Plant Breeding Perspective. Front. Plant Sci., 2020.
6. Yang, Z., Zhang, S., Liu, L., Li, X., Chen, H., Yang, H., Wang, X., Combustion behaviours of tobacco stem in a thermogravimetric analyser and a pilot-scale fluidized bed reactor. Bioresour. Technol. 110, 595–602, 2012.

7. Sun, Y., Cheng, J. Hydrolysis of lignocellulosic materials for ethanol production: a review. Vol. 83. Bioresource Technology, pp. 1-11. 2002
8. Chaturvedi, S., Upreti, D.K., Tandon, D.K, Sharma, A., Dixit A. (2008). Bio-waste from tobacco industry as tailored organic fertilizer for improving yields and nutritional values of tomato crop. Vol. 29. Journal of Environmental Biology No. 5, pp. 759-763.
9. Mile Đ. Peševski, Borče M. Iliev, Dragić Lj. Živković, Violeta T. Jakimovska-Popovska, Marija A. Srbinoska, Blaže K. Filiposki, Possibilities for utilization of tobacco stems for production of energetic briquettes Journal of Agricultural Sciences, Belgrade Volume 55, Issue 1, Pages: 45-54, 2010.
10. Shakhes, J., Marandi, M.A.B., Zeinaly, F., Saraian, A., Saghafi, T. Tobacco residues as promising lignocellulosic materials for pulp and paper industry. Vol. 9. BioResources No. 4, pp. 4481-4493, 2011.
11. Cai, J., Li, B., Chen, C., Wang, J., Zhao, M., and Zhang, K. Hydrothermal carbonization of tobacco stalk for fuel application. Bioresour. Technol. 220, 305–311, 2016)
12. Aleksandre Maisashvili, Henry L. Bryant, and James W. Richardson, Economic feasibility of tobacco leaves for biofuel production and high value squalene. International Food and Agribusiness Management Review, Volume 19 Issue 4, 2016.
13. Mukhtar A, Ullah H, Mukhtar H. Extraction and characterization of tobacco seed oil. Asian J Chem;18:20-4, 2006.
14. Veljković VB, Lakićević SH, Stamenković OS, Todorović ZB, Lazić ML. Biodiesel production from tobacco (*Nicotiana tabacum* L.) seed oil with a high content of free fatty acids. Fuel; 85:2671-5. 2006.
15. Banković-Ilić, I. B., Stamenković, O. S., and Veljković, V. B. Biodiesel production from non-edible plant oils. *Renew. Sust. Energ. Rev.* 16, 3621–3647, 2012.
16. Kumar, M., and Sharma, M. P. Selection of potential oils for biodiesel production. *Renew. Sust. Energ. Rev.* 56, 1129–1138, 2016.

17. Marija Srbinoska, Vesna Rafajlovska., Determination of tocopherols and tocotrienols in tobacco seed oil by a normal-phase liquid chromatography, *Analytical Chemistry: An Indian Journal* Vol.8, Issue 4, 246-251, 2009.
18. Stefka Kirkova, Marija Srbinoska, Silvia Ivanova, Anka Georgieva ., Determination of fatty acid composition of seed of Oriental tobacco, *Тютюн/Tobacco, ()* vol.66, 1-6, 53-58 ISSN 0494-3244, 2016.
19. Marija Srbinoska, Vasilka Najdenova., Vesna Rafajlovska V., Kiril Lisičkov , Characterization of tobacco seed oil and seed cake Proceeding of the 6th Symposium "Novel Technologies and Economics Development", 20-22 Oktomber, Leskovac, Sebia and Monte Negro, CD-ROM, 2005.