BASIC DATA OF TOBACCO STEMS DRYING[#]

Alenka Štefanič Petek,* Janvit Golob
Faculty of Chemistry and Chemical Technology, Aškerčeva 5, SI-1000 Ljubljana, Slovenia

Iris-Ksenija Brkovič
Tobačna Ljubljana, Slovenia

Željko Gorišek
Biotechnical Faculty, Department of Wood and Technology, Rožna dolina – Cesta VIII 34, SI-1000 Ljubljana, Slovenia

[#]This paper is dedicated to Professor Roman Modic at his 90th birthday

Received 05-2001

Abstract
In this work equilibrium and kinetic data for the drying of tobacco stems are presented, which are of great importance for further processing in the manufacture of cigarettes. For three different types of stems sorption isotherms, Luikov's values, difussivities and estimated drying time were determined. The analysis of the process included also mass and heat balances.

Introduction

Drying (curing) is one of the most important operations in the technology of tobacco processing. During the manufacture of cigarettes shredded tobacco stems are added to the main component in order to lower the nicotine and tar content. The quality of the final product depends mainly on physical and chemical properties of components, acquired in previous treatment.

Processing of dried tobacco leaves is a multistep procedure. Stems are separated from tobacco leaves by threshing. After the humidifying (from 10% to 34% of moisture content) they are rolled and cut. To achieve better filling capacity, shredded stems are further exposed to the elevated pressure and temperature to enlarge the volume up to 200 %. Expanded stems are finally dried to 13% of moisture content. Drying of artificially moistened tobacco stems can alter cigarette properties, thus the knowledge of equilibrium and kinetic data for this process is essential. Literature offers very limited information about this field of research.[1-3] The conditions of the tobacco stems drying are very similar to those in the drying process of other plant materials.[4-7]

In order to investigate the influence of drying on the properties of tobacco stems, the goal of this work is (i) to determine equilibrium and kinetic data for three types of stems and (ii) to analyse mass and heat balances in order to estimate the optimal drying conditions.

Materials and methods

1. Equilibrium data

Sorption isotherms and Luikov's parameters demonstrate equilibrium data. Sorption isotherms are usually obtained by weighing the material at equilibrium conditions, achieved at four different relative humidities at the chosen temperature. This method can be used for the determination of sorption curves for different materials.

In this work, sorption and desorption isotherms for two types of Virginia tobacco stems, labeled as ZVUSSA and BVCLSSA, and for Burley tobacco stems, denoted as IBDLS, were determined using the static gravimetric method, developed and standardized in the European COST 90 Project. Four saturated salt solutions ($MgCl_2$, $NaNO_2$, NaCl, $ZnSO_4$) were used to maintain constant relative air humidity at the chosen temperature, as shown in Table 1. Drying of previously humidified stems was carried out at 82 °C.

	Relative air humidity φ (%)	***Equilibrium moisture content of stems*** (X^*) ZVUSSA	BVCLSSA	IBDLS
$MgCl_2$	35	3.28	4.84	3.00
$NaNO_2$	65	17.42	14.87	16.95
NaCl	76	27.27	28.05	27.10
$ZnSO_4$	88	46.83	59.01	47.09

Table 1. Moisture content of tobacco stems at 20 °C

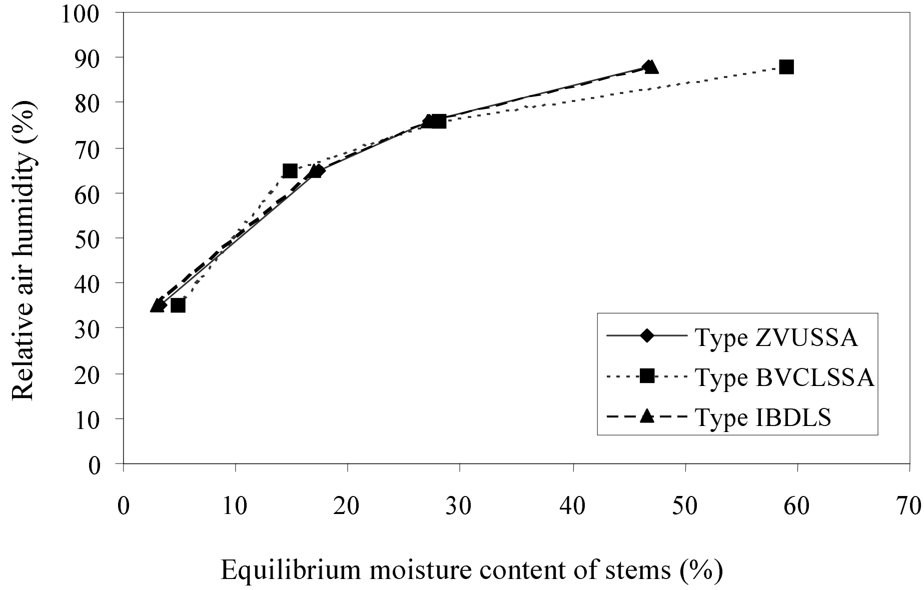

Chart 1. Sorption isotherms for tobacco stems at 20 °C

Experimental data revealed the minimal difference between sorption and desorption isotherms.

Moisture isotherms are usually exponential over most of the moisture-content range. They can be described by the following expression:

$$-a \times \ln \frac{\varphi}{\varphi_o} = \frac{1}{X^*} + b \quad \textbf{(1)}$$

Coefficients *a* and *b* are specific to the given substance. When the boundary values are considered, the equation (1) can be re-written as

$$\frac{1}{X^*} = \frac{1}{X_{max}^{\;\;*}} - a \times \ln \frac{\varphi}{\varphi_o} \quad \textbf{(2)}$$

X^*........equilibrium moisture content of the substance

X_{max}^*...the maximum hygroscopic moisture content of the substance

φ........relative humidity of the air (%)

φ_o......100 % air humidity

Parameters X_{max}^* and *a* are the Luikov's values and characterise the material.[4]

Sorption isotherms at 20 °C for all three types of stems, which are presented in Chart 1, were used in equation (2) to determine maximum hygroscopic moisture content

X_{max}^* and Luikov's value a. It was established that all three types of stems have the same Luikov's value a, which is 6.2. The maximum equilibrium moisture content X_{max}^* is 0.75 for stems labelled as ZVUSSA and IBDLS, and 0.85 for stems of type BVCLSSA.

2. Kinetics of tobacco stems drying

Drying of stems is considered as unsteady state diffusion in medium of defined dimensions, for which the second Fick's law is valid,[8]

$$\frac{dc_A}{dt} = D_{AB} \times \nabla^2 c_A \tag{3}$$

The solution of the second Fick's law for cylindrical coordinates is presented in the Gurney-Lurie's diagram, where the undimensional variables Y for the moisture content, X_D for time and n for the distance from the centre are introduced.

X_D values for tobacco stems were read from the Gurney-Lurie's diagram at the zero values of parameters m (ratio of external/internal resistance) and n. Data from adsorption and desorption processes were used in the computation of diffusivities D_{AB} for all three types of stems according to the following expression:

$$D_{AB} = X_D \times \frac{r^2}{t} \tag{4}$$

Radius of the stem was used as r value (r = 3 mm). Calculations established the same values of D_{AB} for all three types of stems at both processes.

Adsorption time (h)	Y^*	X_D^*	D_{AB} (m^2/s)
3	0.5	0.23	1.92×10^{-10}
15	0.4	0.25	0.42×10^{-10}
70	0.55	0.20	0.07×10^{-10}

Table 2. Diffusivity of tobacco stems at the adsorption process

Desorption time (h)	Y^*	X_D^*	D_{AB} (m^2/s)
3	0.83	0.15	1.25×10^{-10}
15	0.42	0.24	0.40×10^{-10}
70	0.52	0.21	0.075×10^{-10}

Table 3. Diffusivity of tobacco stems at the desorption (drying) process

The great dependence of diffusivity (D_{AB}) on the moisture content (Y) is evident at both processes.

3. Prediction of the drying time

In the drying process the moisture content in stems is decreased from 34 % to 13 %. These data allow the prediction of the time needed to achieve the required outlet moisture content, taking into account the equilibrium moisture content at 20 % relative humidity (c_{Ai} = 2 %). From Gurney-Lurie's diagram the X_D value of 0.25 for $Y = 0.35$ ($m = 0$, $n = 0$) was determined. For the estimated diffusivity ($D_{AB} = 2\times10^{-10}$ m^2/s) and equivalent radius of cut stems ($r_{eq.}$ = 1 mm) drying time was calculated using the equation (4). Theoretical time needed to dry the tobacco stems is 125 seconds and corresponds quite well to the values in industrial process, which are approximately 100 seconds.

4. Mass and heat balances of the tobacco stems drying

The analysis of the stems drying process included also mass and heat balances, which were calculated from data acquired in Tobačna Ljubljana. The inlet flow is 1000 kg/h of tobacco stems having 34% of moisture. The computed flow of dry air needed to achieve the outlet 13% of stems humidity is 10.88 t/h. Heat balance was determined by the standard procedure for the drying operations,[4] where the inlet temperature was 120 ^{o}C and the heat input was 350 kW. It was established that the drying of tobacco stems is carried out at the constant enthalpy (I = 148 kJ/kg), since the most of heat losses are compensated by the heat of fans.

Conclusions

Thermodynamic data manifested by Luikov's values, place tobacco stems into the group of hygroscopic materials of organic origin with typical equilibrium parameters. Kinetic data gave the values of diffusivity D_{AB} in the expected range and revealed its strong dependence on the moisture content of the material. Heat balance of the industrial process showed that the drying of tobacco stems is performed at the constant enthalpy.

Presented data can be used as a basis for the analysis and optimisation of the tobacco stems drying process.

References and Notes

1. Barthakur, N. N.; Arnold, N. P. *Beitr. Tabakforsch. Int.* **1989**, *14*, 321-326.
2. Kiranoudis, C. T.; Maroulis, Z. B.; Marinos-Kouris D. *Drying Technol.* **1990**, *8*, 351-366.
3. Bridges T. C.; Walton L. R.; Ross, I. J. *Trans. ASAE* **1981**, *24*, 1608-1612.
4. Keey, R. B. *Introduction to Industrial Drying Operations,* Pergamon Press, Oxford, 1978.
5. Knez, Ž.; Doleček, V.; Golob, J.; Zupanec, J. *Hopfen-Rundschau* **1985**, 40-42.
6. Zupanec, J.; Golob, J.; Knez, Ž. *Vestn. Slov. Kem. Drus.* **1989**, *36*, 215-222.
7. *Book of Abstracts* (Mooiweer G. D.; Coumans, W. J., eds.) 12th International Drying Symposium, Noordwijkerhout, The Netherlands, 2000.
8. Koloini T. *Prenos toplote in snovi*, Univerza v Ljubljani, Ljubljana, 1993.

Povzetek

V članku so predstavljeni ravnotežni in kinetični podatki, pridobljeni pri sušenju tobačnih žil, ki so pomembna surovina za izdelavo cigaret. Na podlagi izoterm navlaževanja in sušenja treh tipov tobačnih žil smo izračunali Luikove parametre, difuzijske konstante in teoretični čas sušenja. Vrednost Luikovega parametra *a*, ki je za vse tri vrste žil enaka in znaša 6,2, uvršča tobačne žile med higroskopne organske materiale z zanje značilnimi ravnotežnimi parametri. Kinetični podatki o difuzivnosti so v pričakovanem območju, kažejo pa veliko odvisnost od vlažnosti materiala. S toplotno bilanco procesa smo ugotovili, da poteka sušenje tobačnih žil pri konstantni entalpiji, saj se vse toplotne izgube pokrivajo s toploto motorjev in ventilatorjev.

Dobljeni rezultati raziskave sušenja tobačnih žil lahko služijo kot osnova za analizo in optimizacijo tega procesa.