INVESTIGATION OF MOISTURE CONDITIONS DURING TOBACCO DRYING

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REZUMAT. Scopul cercetării a fost de a stabili diagrama experimentală a umidităţi la uscarea frunzelor de tutun. Un model simplu experimental a fost aplicat pentru calcularea raportului de umiditate. Măsuratorile au fost efectuate într-o cutie-climat, studiind diferite frunze de tutun. Două cicluri de măsurare au fost executate in timpul de lucru al ultimei cercetări. În primul rând frunzele de tutun au fost agăţate în starea lor naturală, iar în al doilea studiu midrib-ul a fost eliminat de pe frunzele de tutun. Conform aşteptărilor noastre, deshidratarea frunzei de tutun mutilată - eliminând midrib-ul - a fost mult mai rapida decât uscarea frunzei întregi.Deshidratare midrib-ul a fost considerabil mai lenta decât comportamentul foiţei. Un rezultat important a fost că funcţia exponenţială Walton este potrivită pentru a descrie dezumidificarea. Concluzia definitivă este că coeficientul de uscare a crescut puternic prin creşterea temperaturii de uscare.

Cuvinte cheie: raportul de umiditate, coeficientul de uscare, modelul exponenţial, coeficientul de difuzie

ABSTRACT. The purpose of the investigation was to determine moisture relationship experimentally at drying of tobacco leaves. A simple experimental model was applied for calculating moisture ratio. The measurements were done in a climate box, studying different tobacco leaves. Two measuring cycles were executed during the latest research work. First the tobacco leaves were hung up in their natural condition, but in the second trial the midrib was removed from the tobacco leaves. According our expectation, the dehydration of the mutilated tobacco leaf - eliminating the midrib - was much quicker than drying of the whole leaf. The dehydration of the midrib was considerably slower than the behaviour of the lamina. An important result was that the Walton exponential function is suitable for describing dehumidification. Final conclusion that the drying coefficient increased vigorously by raising of drying temperature.

Keywords: moisture ratio, drying coefficient, exponential model, diffusion coefficient.

1. INTRODUCTION

During the dehydration, the tobacco is very sensitive to changes in the technological parameters. The relationship between the tobacco leaf and its environment is not well defined. Therefore, a method was established for determination of the most important thermophysical and transport properties of the leaf, e.g., variation of surface temperature, and the thermal diffusivity, with special regard to the binding and diffusion energy of water in tobacco or other agricultural products [6].

Different applied theoretical and experimental methods exist for determination of the basic characteristics of the drying tobacco leaf, so we had some possibilities to use a suitable system during the research work.

One of the successful ways was the numeric method, it controlled the drying process of the basic parts of tobacco leaf by mathematical methods. The continuous changing of dehydration and surface temperature of the whole leaf could be monitored by a computer program. This program was suitable for estimation of model parameters, using the measurement results [1].

Evaporation and heat development, the most important surface changes, may be fully characterised by examination of mass transport. The analytical model, which described the heat development on the leaf surface, provides an opportunity to estimate several typical parameters (α, λ, ρ, c). The model requires a method of measurement involving a controlled environment box whose parameters may be fixed.

The accuracy of the thermal material characteristics we have determined with the numerical model may be improved by increasing the number of measurements. Conditions for the measurements should match those typically employed during actual tobacco curing technology. This was done for some determinations of the thermal properties of the tobacco leaf during experimental curing. Surface temperature changes were monitored with an infrared camera [5].

The series of the pictures showed the differences among the different parts of the leaf. It was concluded, that the temperature of the leaf surface was only homogeneous at the end of the drying. The temperature was lower at the midrib. Presumably, the features of the material changed at the different components of the tobacco leaf.

2. THEORY

The purpose of the research work was to find and experimentally determine the applicability of the mathematical models for the moisture content of the dried tobacco lamina and midrib.

The applied mathematical model for the rate of the average moisture content of the lamina as a function of time was described in the following way [9] (1):

$$\Theta(t) = \sum_{n=0}^{\infty} \frac{2}{(\lambda_n \cdot L)^2} \cdot e^{-D\cdot\lambda_n^2\cdot t} \qquad (1)$$

where: Θ = moisture ratio, L = half thickness of the lamina (m), $\lambda_n = \frac{(2\cdot n+1)\cdot\pi}{2\cdot L}$ (m^{-1}), n = 0, 1, 2, …., D = diffusion coefficient based on the mass of water per unit mass of solid $(m^2 s^{-1})$, t = time (s).

It is well-known that the sorption isotherms change near linearly with the following equation [7] (2):

$$\frac{dM}{dt} = -k(M - M_e) \qquad (2)$$

where: M = moisture content at time t, dry basis, percent, M_e = equilibrium moisture content, percent, k = drying coefficient (h^{-1}), t = time of drying (h).

The solution of the mentioned differential equation (3):

$$\frac{M - M_e}{M_0 - M_e} = e^{-kt} \qquad (3)$$

where: M_0 = initial moisture content, percent.

The value of "k" can be determined by a regression approaching on the base of the moisture ratio. The moisture ratio can be calculated by using the results of the experimentation (4):

$$\Theta = \frac{M - M_e}{M_0 - M_e} \qquad (4)$$

Several assumptions were made at determination of the during and mass diffusion coefficients:

- each component is a homogeneous material;
- the moisture content of the tobacco is a linear function of leaf temperature and vapour concentration in the pore spaces;
- the diffusion coefficient is a constant for a given environmental condition;
- the moisture in the pore space of the leaf is in the vapour phase.

A suitable method was developed for determination of the diffusion coefficient – characterising of material transport – by some well-known mathematical expressions for moisture content of tobacco leaf. The most suitable formula was produced by adjusting of the practical drying parameters and periodical measurement of the water content, consideration for the thickness of tobacco leaf [2].

3. EXPERIMENTATION

The measurements were done in a climate box, studying of different tobacco leaves. The test parameters were adjusted according to the suggested technological features of drying air. The examinations were completed after reaching of the equilibrium (constant) moisture content. The whole drying process was measured to reach the isothermal condition (reading of the instruments in every 4-8 hours).

Two measuring cycles were executed during the latest research work. First the tobacco leaves were hung up in their natural condition, but in the second trial the midrib was removed from the tobacco leaf, so we could examine the pure lamina and midrib. At the end of the two cycles the tobacco leaves were exsiccated on 105^{o}C. The measured mass was considered as the dry matter of the tobacco. The specific dry matter was calculated with the rates of the masses.

The Figure 1 shows the experimental drying of the matured tobacco leaves, hanging up as natural produce.

Fig. 1. *The normal tobacco leaves in the dryer*

Table 1. *Conditions of the measurements*

Drying period, t (h)	Drying temperature, T (^{0}C)	Relative humidity, φ (%)
0	32	90
30	38	85
44	40	80
55	44	78
80	47	70
84	48	65
105	51	54
113	57	36
142	63	25

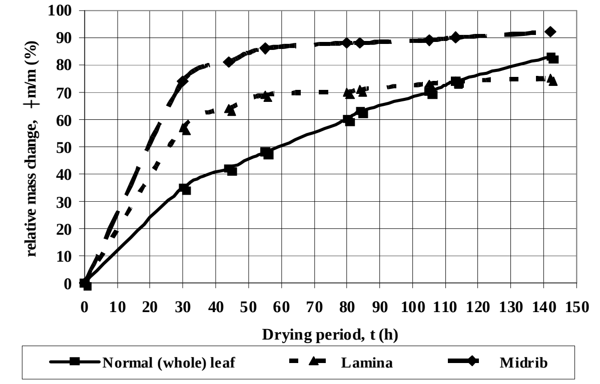

Fig. 2. *Test parameters of the experimental drying*

4. RESULTS AND DISCUSSION

The Table 2 contains the results of the experimental curing (drying), with special regards to change of the mass (Δm) against the time (t), (m = mass at the end of a given drying period).

Table 2. *The average mass change during dehydration*

Time, t (h)	Relative mass change, (Δm/m) x 100, %		
	Normal (whole) tobacco leaf	lamina	midrib
30	35	57	74
44	42	64	81
55	48	69	86
80	60	70	88
84	63	71	89
105	70	73	89
113	74	74	90
142	83	75	92

After drying of the different tobacco leaves we determined the equilibrium moisture content (M_e) for calculating the moisture ratio (Θ). In this way we could estimate the drying coefficients (k), according the Table 3.

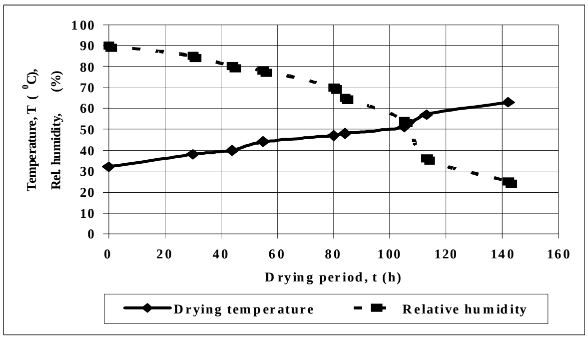

Fig. 3. *The relative mass change of the different tobacco samples*

Table 3. *Calculated values of the drying coefficient*

Drying temperature (^{0}C)	Drying coefficient, k (h^{-1})		
	normal (whole) leaf	lamina	midrib
38	0,0490	0,0454	0,0394
40	0,0673	0,0628	0,0651
44	0,1286	0,1547	0,1030
47	0,1338	0,1666	0,1057
48	0,5602	0,7589	0,3953
51	0,7750	0,8334	0,4208
57	1,6770	1,7650	0,5521
63	1,8709	2,2650	0,9434

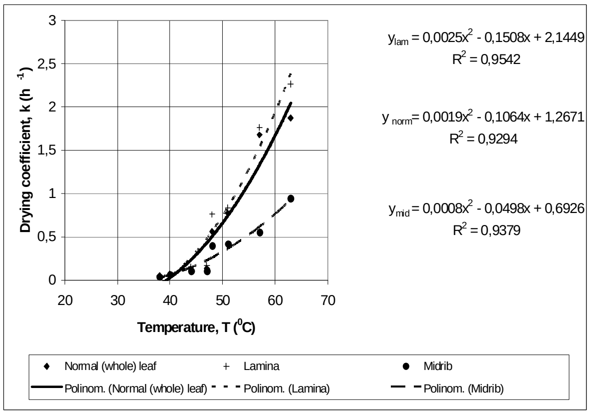

Fig. 4. *Change of the drying coefficients*

For determination of the mass diffusion coefficients, we applied the mentioned Walton formula. On the base of changing of the mass we calculated the moisture content against the temperature and relative humidity regarding the lamina part of the leaves.

Applying the formula the diffusion coefficients (D) were estimated gradually as a function of time, temperature and relative humidity. We fitted the equation to the data of the moisture contents, using the method of minimizing the sum of squares of the differences between observed and predicted values of the moisture ratio (Θ), through an iterative process. The computer parameter was the mass diffusion coefficient that gave the best fit of the equation to the experimental data. The estimated mass diffusion coefficients are shown in Table 4. At the time periods we examined the same samples, not new ones. So the tobacco was more and more dried, approaching the end of the process [3].

Table 4. *Average mass diffusion coefficients (D) as a function of time (t), temperature (T) and relative humidity (φ)*

t (h)	**T (°C)**	**φ (%)**	**D (m^2s^{-1})x10^8 (lamina, sorption)**
30	38	85	12,695
44	40	80	15,163
55	44	78	20,106
80	47	70	30,503
84	48	65	35,729
105	51	54	48,096
113	57	36	119,250
142	63	25	221,419

5. CONCLUSIONS

The main conclusion was that the initial relative humidity of the drying cycle was decisive importance for the whole curing process.

The finest drying process happened when the relative humidity was about 80% in the climate chamber, applying some overriped (yellowed) tobacco leaves.

According our expectation, the dehydration of the mutilated tobacco leaf – eliminating of the midrib – was much quicker than the drying of the whole leaf. The dehydration of the midrib was considerably different than the behaviour of the lamina or the complete leaf [4].

The results confirmed that the applied model was sufficiently accurate in describing the experimental moisture curves. The model describes well the nature of the moisture transfer process of the lamina. The range of the calculated mass diffusion coefficients accord well with the data described previously in the different tobacco reports. The mass diffusion coefficient of the lamina and midrib is analogous to the vapor diffusion coefficient of packed flue-cured leaves determined by [8].

The moisture content of the midrib as a function of time is different than the moisture change of the lamina, so it needs to apply a modified mathematical model for describing the nature of the midrib.

An important result that a suitable mathematical model for the drying coefficient is the simple exponential equation which includes the drying coefficient but not characterise change of diffusion [9].

6. REFERENCES

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