



CORESTA SSPT 2015 | Meeting theme

Analysis Of Process Intensity on Tobacco Moisture Retention Based on Uniform Design

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Presentation outline

- Introduction
- Research overview
- Results
- Preliminary conclusions
- Continuing research
- Questions



Introduction

- Tobacco moisture retention provide essential information about moisture adsorption behavior and physical characteristics of cigarette
 - Equilibrium moisture content
 - Water adsorption and desorption rates
- Process intensity do change the moisture adsorption and desorption behaviors
 - The fiber distribution patterns
 - The cellular contents

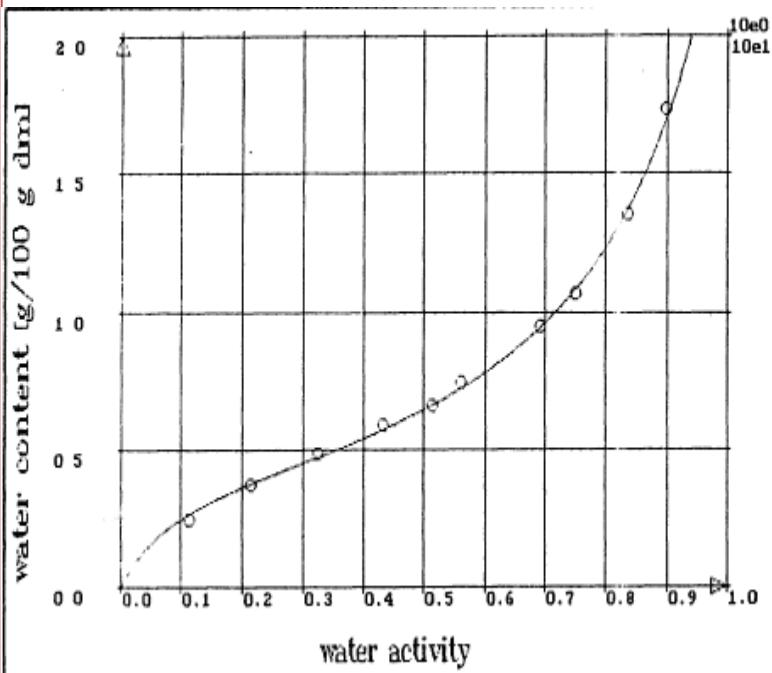
Introduction

Equation	Equilibrium moisture content model
Modified Henderson (Henderson, 1952; Thompson et al., 1968)	$M_e = \left[-\frac{\ln(1-a_w)}{A*(T+B)} \right]^{\frac{1}{C}}$
Modified Oswin (Chen,1988; Oswin,1946)	$M_e = (A + B * T) * \left(\frac{a_w}{1 - a_w} \right)^{\frac{1}{C}}$
Modified Halsey (Halsey,1948; Chrife & Iglesias, 1978)	$M_e = \left[-\frac{\exp(A + B * T)}{\ln a_w} \right]^{\frac{1}{C}}$
Modified GAB (Anderson,1946; De Boer,1953; Guggenheim,1966; Jayas & Mazza,1993)	$M_e = \frac{A * B * \left(\frac{C}{T} \right) * a_w}{(1 - B * a_w)[1 - B * a_w + \left(\frac{C}{T} \right) * B * a_w]}$

Equations	Parameters			R^2	SE	Residuals
	A	B	C			
Modified Henderson	$2.160 * 10^{-4}$	25.538	1.632	0.987	0.469	Random
Modified Oswin	13.041	-0.067	2.509	0.965	0.763	Patterned
Modified Halsey	V_m	2.452	-0.008	1.935	0.936	Patterned
Modified GAB	12.752	0.507	220.039	0.994	0.308	Random

Introduction

- Monolayer moisture content



Wood species	Adsorption branch		
	V_m [cm ³ /g]	c	k
Sycamore	0.045	12	0.79
Japanese cypress	0.050	12	0.76
Mahogany	0.050	14	0.81
Lime	0.050	6.3	0.75
Elm	0.053	15	0.81
Fir	0.055	14	0.79
Pine	0.057	9.6	0.77
Birch	0.058	8.9	0.78
Beech	0.058	9.4	0.79
Oak	0.058	7.4	0.77
Walnut	0.059	7.3	0.69
Cherry	0.059	9.9	0.72
Sour cherry	0.059	10	0.77
Poplar	0.060	9.6	0.73
Alder	0.0597	6.6	0.71
Rosewood	0.061	9.3	0.66
Willow	0.066	8.0	0.73
Ash	0.066	8.9	0.68
Spruce	0.068	10	0.74
Apple tree	0.068	7.7	0.73

Research overview

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Middle leaves

30kg/h

50 °C - 55 °C

Uniform design

Parameters gradient setting for process intensity (n=3)

Process intensity	Treatment	Processing time/s	Blast temperature/°C	Processing capacity/kg	steam flow compensation /kg/h
Weak	T1	210	90	10	10
	T2	210	atmospheric temperature	9	20
	T8	210	atmospheric temperature	10	30
High	T4	240	110	9	10
	T6	180	110	9	40
	T7	240	90	10	40
Medium	T3	240	100	11	30
	T5	180	100	11	20

The raw materials was used as control

Research overview

Setup | Climate | Samples | Measurement | Results

Load Save Default

Time between weighting cycles	<input type="text" value="10"/> min
Minimum time per climate setting	<input type="text" value="50"/> min
Maximum time per climate setting	<input type="text" value="50"/> h
Default Weight Limit	+ <input type="text" value="100"/> %
Equilibrium Bandwidth dm/dt	+/- <input type="text" value="0.01"/> % / <input type="text" value="30"/> min

SPSx-1μ: Setup

Setup | Climate | Samples | Measurement | Results

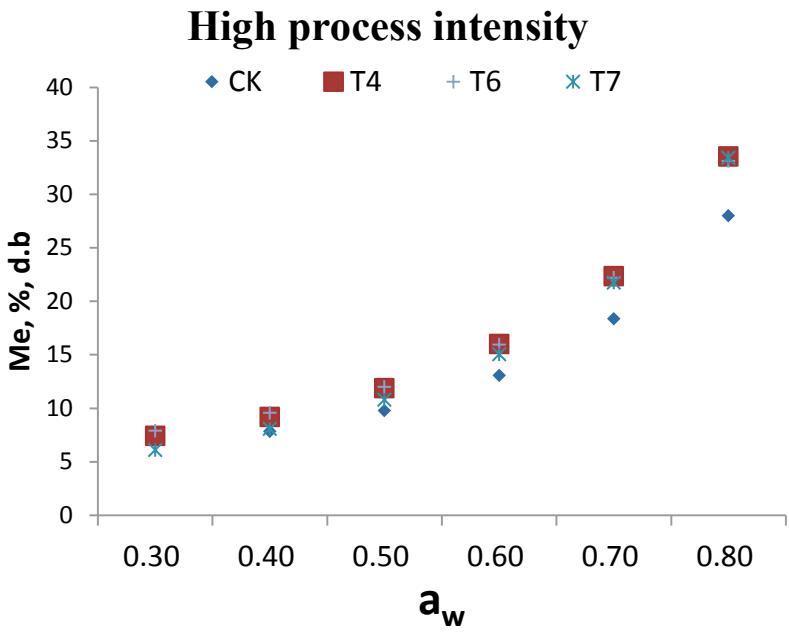
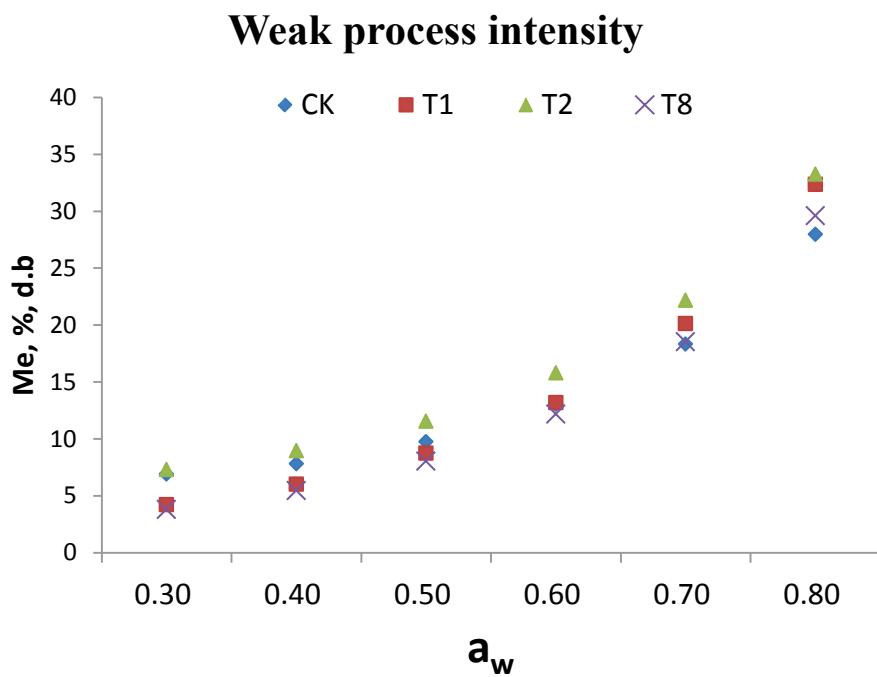
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Cycle	Humidity	Humidity	Time	Steps	Temperature
No.	Start	Stop			
	[% r.H.]	[% r.H.]	[h]		[°C]
1	30.00	50.00		1	25.00
2	50.00	70.00		1	25.00
3	50.00	30.00		1	25.00
4					
5					

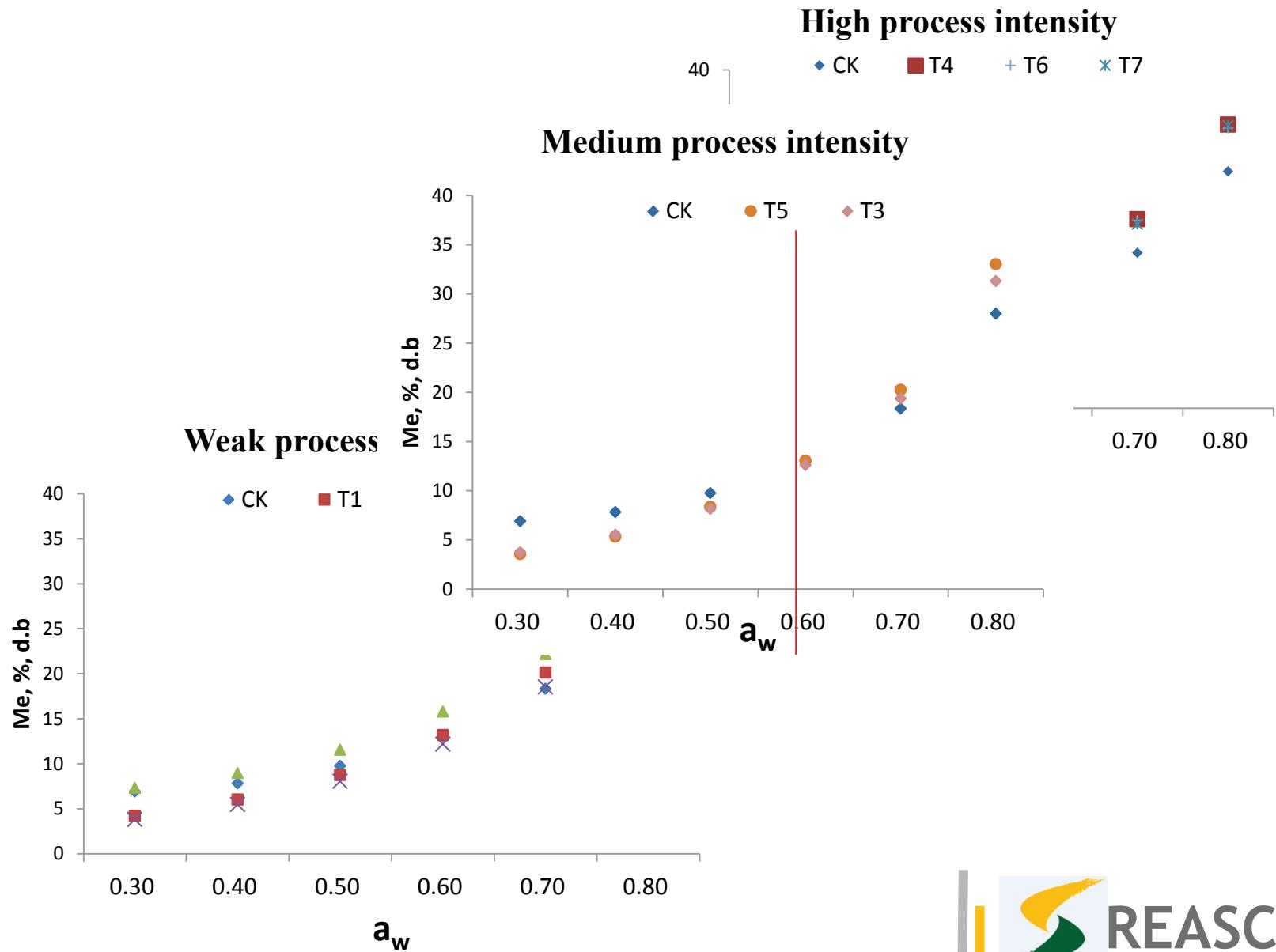
Climate

SAS : Non-linear and quadratic regression

Result



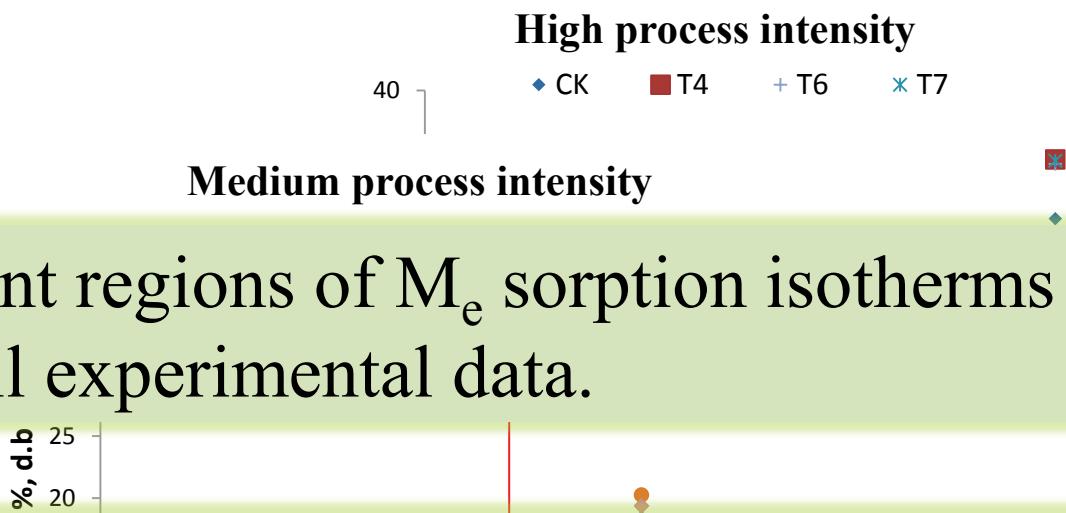
Result



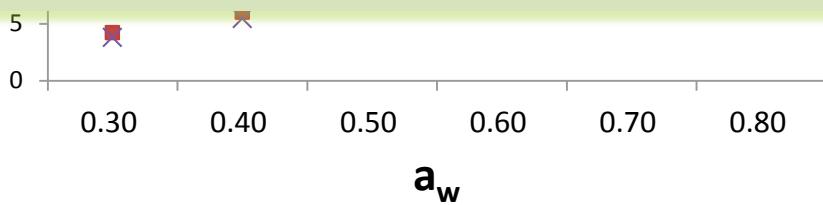
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Result

- Two different regions of M_e sorption isotherms at a_w 0.6 for all experimental data.



- Medium process intensity showed the similarity to weak process intensity.
- relative different behavior over the three process intensity level was observed, however, not so obviously as we expected.



Result

GAB constants obtained from the non-linear regression of tobacco moisture content at different casing process intensity

Experiments	v_m	k	C	R^2	S.E	Residual
CK	6.076	1.000	5.745	0.9986	0.276	Random
T1	7.152	0.980	2.213	0.9997	0.182	Random
T2	7.372	0.992	4.584	0.9989	0.293	Random
T3	7.643	0.951	3.648	0.9998	0.144	Random
T4	7.405	0.992	4.863	0.9994	0.229	Random
T5	7.710	0.952	2.616	0.9999	0.101	Random
T6	7.016	0.998	7.436	0.9993	0.222	Random
T7	7.767	0.991	2.624	0.9999	0.178	Random
T8	6.998	0.953	2.812	0.9998	0.132	Random

The v_m of tobacco with medium process intensity (treatment T5 & T3) got significant increment.

Result

Effective factors with casing process was obtained from backwards quadratic regression model

Parameters	$v_m, R^2 = 0.905, P < 0.05$		
	Coefficient estimated	T value	p.
X2	1.34	4.43	0.017
X3	-0.98	-7.62	0.005
X2*X4	1.92	3.42	0.042
X3*X4	-2.21	-3.85	0.031

X2: Blast temperature, X3: Processing capacity, X4: Steam flow compensation

Working temperature and steam flow compensation response on monolayer moisture content for tobacco moisture retentivity

Preliminary conclusions

- Medium, high or weak process intensity had changed tobacco moisture, but no significant difference.

- GAB model showed acceptable goodness-of-fit for tobacco water sorption curves
- Processing generally improved the tobacco v_m and medium process intensity performed superiority

- Blast temperature and steam flow compensation were considered to be important reasons to satisfy tobacco moisture retention



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Continuing research

- Tobacco leaves were proved the multilayer sorption material
- Isosteric sorption heat rises as the temperature decrease and water activity grow. This mainly caused by the amount of energy required to remove the water molecules was very high at low temperature.
- For many biomass materials, higher isosteric sorption heat probably gives a stronger moisture retentivity. Thus, isosteric sorption heat might be a valid resource for evaluating tobacco moisture retention



Thanks!

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