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Shelf-life prediction of packaged cigarette subjected to different degrees of sealing

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봉함도에 따른 포장담배의 저장수명 예측

이근회, 김영호, 이영택, 임광수, 김용태

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초 록

저장온도, 상대습도 및 봉함도에 따른 유연필름 포장 담배의 저장수명을 컴퓨터를 이용하여 예측한 수치와 실험치를 Student's t test한 결과 $\alpha=0.01$로 높은 정확도를 나타냈다. 근본적으로 저장온도가 높을수록, 또 초기의 평형습도 차가 클수록 저장수명은 짧아졌으며 비교적 고온에서 water vapor의 이동이 더 높게 일어났다. 저장수명에 대한 온도, 봉함도, 상대습도등의 기여도가 SPSS를 이용한 통계분석에 의하면 각각 -0.49, -0.39, -0.28로 저장수명 요인중 봉함도(Sealing degree)도 수명을 단축시키는 주요 인자임을 밝혔으며 포장담배를 6개월 이상 유통시키기위해서는 film포장의 봉함도가 600㎖/min, 30mmH_2O이하가 되어야함을 알 수 있었다.

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"영문 및 국문"

ABSTRACT

In order to predict the shelf-life of cigarettes packaged in typical flexible film under conditions of various temperature, relative humidity and sealing degree, a computer iterative technique was used. Although there were some significant differences at initial equilibrium relative humidity(55%), the experimental results agree fairly well with predictions following the student's t test(α=0.01) in most cases.

Essentially, the higher the storage temperature, the shorter the shelf-life of the cigarette product. The bigger the differences from the initial equilibrium relative humidity, the shorter the storage period of the cigarette. Moisture transfer through the film at relatively high temperature gave higher confidence. The sealing degree, one of the storage parameters, appeared to be a major influencing factor to shelf-life.

Slopes(β) of the temp., sealing degree and %rh of the dependent variable to shelf life were -0.49, -0.39 and -0.28 respectively, when analysed by multiple regression of SPSS software. Below 600mℓ/min sealing degree of the packed cigarette through the sealing position at 30mmH_2O differential pressure, the shelf-life could be increased by more than six months.

INTRODUCTION

The weight change through a packaging material depends on the water sorption isotherm of the cigarette and the conditions of temperature, relative humidity stored, the water vapor permeability and the sealing degree of the packaging material. Oswin[5,6,7] was the first to introduce equations to predict moisture loss from cigarette and suggested solutions for prediction of moisture transfer in a packaged food under steady state temperature and %rh conditions. Karel and his coworkers modified Heiss' mathematical models developing computer solutions.

Veillard et al.[12] and Lockhart[3] have developed similar solutions for predictions of moisture transfer during storage of both foods and drugs. Proctor et al.[8] investigated water vapor permeability at given temperature and relative humidity conditions. Salwin[9] developed a procedure to predict moisture transfer, in combinations of dehydrated foods, from the knowledge of the sorption isotherms of individual components used isotherm plotted line and calculated equilibrium water activity.

Seasonal variation of what in fresh fruit has been reported by many investigators[1,4,10,11] and a more realistic prediction method against fluctuating temperature and relative humidity using the Fourier series was developed by Lee. Y.C.[2]

In the present work, We investigated the shelf-life of the packed cigarette considering the various store temperature, relative humidity and sealing degree. Our major purpose is to clarify how a combination of kinetic data obtained from laboratory test and of new conception on sealing degree of the package. It may be used to predict the lengthened or shortend shelf-life of the cigarette during storage and this approach can be used for selection of storage environments best suited for the desired quality of packed cigarette.

EXPERIMENTAL

Packaging Sample preparation

The films are made of 0.023mm average thick with packed area of 0.0145㎡. For separate determination of the water vapor permeability of the complete package and that of the packaging film itself, Cups method(TAPPI 488) was used to determine the moisture permeability of that film and the result was 3.25 g/㎡daymmH_2O. Thus, It was possible to assume the effect of the barrier and the sealed defects on the moisture transfer rate.

Storage test

Packed cigarette containing some sealed defect products were stored on the various tempearture(10~40℃) and %rh(11~92%) chamber furnished with electric fan for inner Air circulation and weighed it periodically.

Sealing degree test

To elucidate the effect of sealed state, one of the major paramaters for longer shelf-life we have taken up the self designed sealing tester, the pneumatic flow digram of which is illustrated in fig. 1.

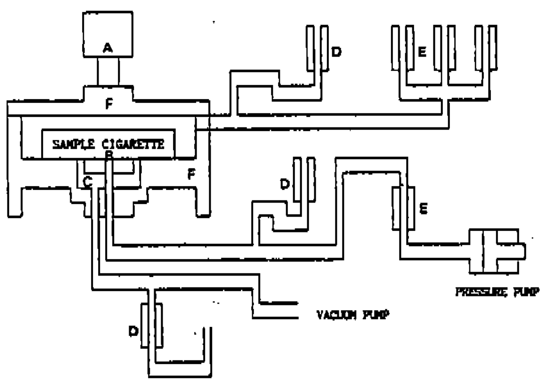

Fig. 1. A pneumatic flow diagram of sealing tester. Details on measuring apparatus ; A : cylinder, B : center hole for pressure air, C : outer groove for suction, D : manometer, E : flow meters, F : measuring head

Many cigarettes packed with flexible film sold in the world market showed a wide variation of sealing degree(0~1400㎖/min at 30 mmH_2O, ΔP) and the results were obtained by the above apparatus.(Fig. 2)

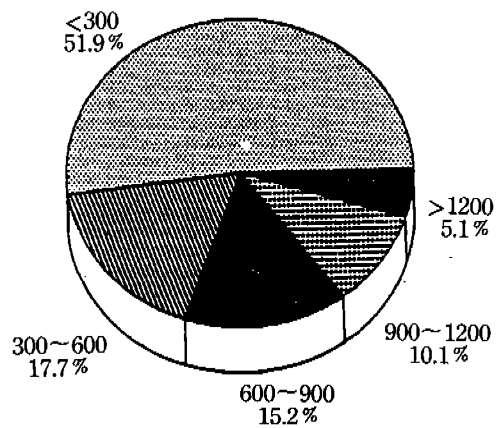

Fig. 2. Pie-graph showing sealing degree of the packed cigarette sold in the world and represented ㎖/min at 30mmH_2O, differential pressure in sealing degree.

Computations for shelf-life prediction

Non-linear regression analysis was used for evaluation of the complex models. This analysis was conducted on the computer with a modification of Michigan State Univ. method. A program to perform these calculations was developed in Basic language and the outputs were compared to the actual results. The flow chart of the computer iterative technique program is shown in Fig. 3.

where ; HE = Outside relative humidity(%)
Wt = Net weight of the product(g)
Ws = Solid weight of the product(g)
Mc = Moisture content of the product (%)
Tf = Film thickness(mm)

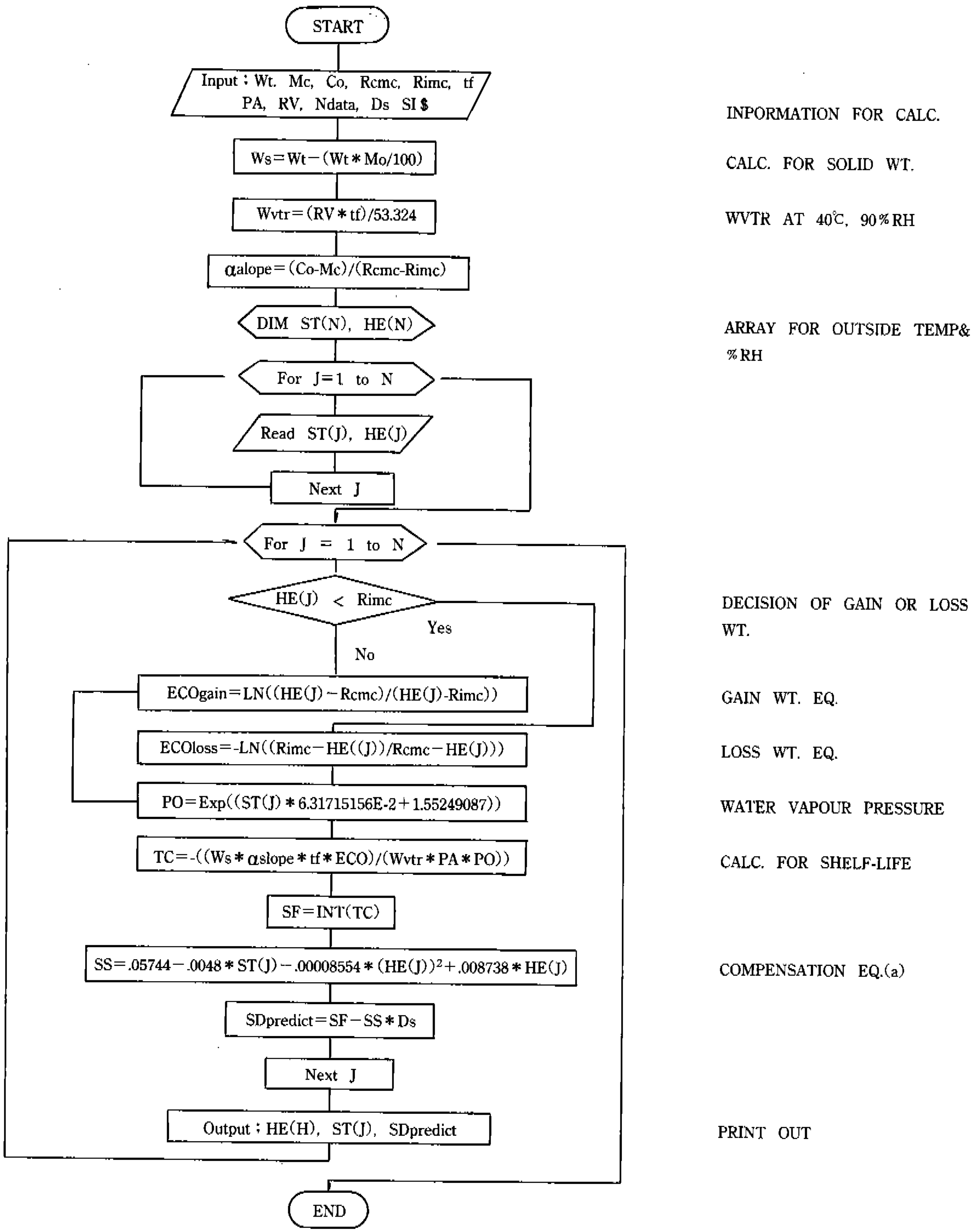

Fig. 3. Flow chart of computer iterative calculation in moisture gain or loss for packed cigarette.

Rimc=Equilibrium %RH at critical moisture content(%)
SF, SDpredict=Calcultated shelf-life time of the product(day)
ST=Outside temperature for storage (℃)
Rv=Water vaper permeability through packaging materials (g of water/day.㎡.mmHg)
PA=Packaging Area(㎡)
PO=Vapour pressure at given temperature(mmHg)
Ds=Sealing degree of the product(㎖/min, 30mmH_2O)

Results and discussion

Moisture adsorption isotherm of the cigarette shreds.

The relationship between relative humidity and equilibrium moisture content in cigarette shreds at 20℃ is illustrated in Fig. 4, which shows the adsorption isotherm of cigarette shreds and the results show a characteristic shape of low moisture content of food isotherm.

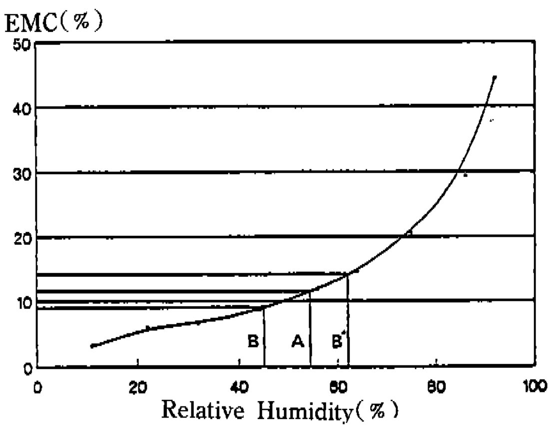

Fig. 4. Sorption iostherm of equilibrium moisture content(%, EMC) versus relative humidity(%) in cigarette shred at 25℃ and showed a critical(B, B') & initial moisture(A) content of the product.

Critical and initial moisture content Limit

As the sorption isotherm of cigarette shreds shows in fig. 4 above, the moisture content rises rapidly when the cigarette shred is exposed to high relative humidities, especially reach at 70% RH.

Table 1. Determination of low limit of ciritical moisture content in cigarette using by Hedonic scaling method. The abbreviations* were A ; like very much, B ; like moderately C ; like slightly, D ; neither like nor dislike, E ; dislike slightly, F ; Dislike moderately, G ; dislike very much.

Rank	Score	%Rh at 56	%Rh at 44
A*	3	3	0
B	2	6	0
C	1	1	0
D	0	0	0
E	-1	0	3
F	-2	0	5
G	-3	0	2
Difference(D)			3

· Sum of the score at different two Relative humidity value/2−D=47

Table 2. Determination of high limit of critical moisture content in cigarette using by Hedonic scaling method. The abbreations* were the same as in table 1.

Rank	Score	%Rh at 56	%Rh at 64
A*	3	4	0
B	2	5	0
C	1	1	0
D	0	0	0
E	-1	0	1
F	-2	0	2
G	-3	0	7
Difference(D)			-3

· Sum of the Score at different two Relative humidity/2−D=63

Following the sensory test results obtained, smokers felt that cigarette product has no more smoking value when either the moisture content of the product 14.1%, ERH 63%(high limit of CMC) or drop below to 9.3%, ERH 47%(low limit of CMC).

The actual data of the shelf-life in the cigarette were evaluated by the multiple curve regression and the results were summarized as following tables(3,4).

Table 3. Multiple curve regression analysis of actual shelf-life in the cigarette

Variables	Regression	Beta(β)	Std. Error B	F
Temp	-11.49975	-1.29044	3.60763	10.161
SD*	- 0.09215	-0.39238	0.01674	30.297
RH^2	- 0.075833	-2.38041	0.01443	27.629
RH	7.736419	2.10396	1.66522	21.584
$Temp^2$	0.141125	0.80438	0.07103	3.948
Constant	180.5596			

*SD ; sealing degree

Table 4. ANOVA table of the multiple curve regression.

	DF	SS	MS	F
Regression	6	500649 80880	83441 63480	20.7539**
Residual	73	293498 57870	4020 52848	

$R^2 = 0.8240$

Table 5 presents a comparison of the experimental and the predicted shelf-life of the cigarette sample. There was no big difference using statistical analysis for all cases suggesting that the mathematical model used in this study predicts well the net weight changes in cigarette packaged in flexible film and the obtained results show a significance at 0.01% level using student's t test(t(158 ; 0.005)=2.576), therefore the program could

Table 5. Relationship between the actual and predicted value of the shelf-life in cigarette.

Temp	%Rh	Range of Sealing Degree(mℓ/min)				
		0	300	600	900	1200
10℃	22	140(135)*1	96(109)	72 (82)	45 (56)	31 (29)
	44	639(626)	417(507)	334(388)	209(270)	146(151)
	75	193(252)	139(216)	111(180)	69(144)	48(108)
	92	110(119)	77 (98)	61 (78)	38 (57)	27 (37)
20℃	22	78 (72)	48 (57)	36 (43)	24 (28)	17 (13)
	44	311(333)	222(275)	171(218)	110(160)	78(103)
	75	119(134)	81(110)	65 (86)	41 (62)	28 (39)
	92	65 (63)	41 (51)	33 (39)	20 (27)	15 (15)
30℃	22	40 (38)	26 (31)	20 (23)	13 (16)	9 (8)
	44	183(177)	116(143)	92(108)	58 (74)	40 (39)
	75	76 (71)	43 (56)	35 (42)	23 (28)	15 (14)
	92	39 (33)	21 (26)	17 (18)	11 (11)	7 (3)
40℃	22	22 (20)	13 (16)	11 (12)	7 (8)	5 (4)
	44	106 (94)	63 (73)	50 (53)	31 (33)	22 (13)
	75	36 (37)	22 (30)	19 (24)	11 (17)	8 (10)
	92	29 (18)	12 (13)	10 (7)	6 (2)	5 (1)

*1 ; The computer predicted data were shown in parentheses.

be appliable to other agricultural product whenever variable outside environments are given.

Relationships between variables(temp., sealing degree and %Rh) of the experimental data were evaluated by calculating correlation coefficients and multiple curve regression using SPSS software and the slopes(β) of the temp., sealing degree and %rh to the dependent variables, shelf-life were -0.49, -0.39 and -0.28 respectively.

Although there were some significant differences in 56% and 64% RH among the outside environment, it was found that the results of shelf-life tests were very close to the predictions of the computer program. The equation(a) obtained for calculation of real shelf-life for packed cigarette was extrapolated to computer iterative technique software.

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