Journal of the Korean Society of
Tobacco Science Vol. 27, No. 1, 134～140 (2005)
Printed in Republic of Korea

Discrimination of Korean Tobacco's Aroma and Tastes using the Electronic Nose/Tongue and Their feasibility in Tobacco Sensory Evaluation

Whan-Woo Lee*, Seung-Yong Lee, Hyun-Joo Shon and Young-Hoh Kim
KT&G Central Research Institute
(Received May 31, 2005)

ABSTRACT : The purpose of this study was the discrimination of different tobacco types by the E-Nose/tongue and the analysis of what human sensory attributes are correlated with e-instrument's sensors. Samples were made from five groups of Korean domestic tobacco leaves, aged burley and not aged, aged flue-cured and not aged and blending types of the four. Instrumental tests were conducted to discriminate characteristics among different tobacco samples by the E-Nose and the E-Tongue. Sensory attributes of tobacco tastes were impact, irritation, bitterness, hay-like, tobacco taste, smoke volume, smoke pungent and mouth cleanness. *STATISTICA* software was used to analyze correlation between the human sensory data and the raw data of e-instruments. Discrimination analysis can be achieved using principal components analysis(PCA) and discriminant factorial analysis(DFA). As a result, impact, bitterness, irritation, smoke volume and smoke pungent of human sensory attributes were correlated with data from the several clustered E-Nose sensors($p < 0.10$). And bitterness, irritation, and smoke pungent of human sensory attributes were correlated with data from the E-Tongue sensors($p < 0.10$). PCA plot by the E-Nose shows that aged tobacco and not aged were discriminated and DFA plot shows that three groups(aged burley, not aged burley and flue-cured) were discriminated. PCA plot by the E-Tongue shows that flue-cured tobacco was separated from burley. Our results indicated that the e-instruments are sensitive enough to distinguish among tobacco types and their several sensors are reacted to the human sensory attributes.

Key words **: sensory evaluation, electronic nose, electronic tongue, QDA**

In tobacco sensory evaluation, sensitivity, repeatability, reproducibility, tiredness to the sample and subject's condition are very important factors for reliability. The human sensory result is frequently a non-linear or non-sensitive response to the tobacco. A number of chemical analysis methods are used to evaluate tobacco's complex characteristics. These methods may be a disadvantage in that humans perceive aroma and tastes holistically(Furlong, C. et al., 2002). Analysis by trained sensory panels does provide a method of holistic analysis, but this method is costly, time consuming and subjective. Recently sensor technology has been very rapidly improved. E-nose has a detection level in ppb. E-tongue has in ppm. Detection threshold of human organic sensor varies individually between 1000 ppm and 1 ppt (Chmielewski, J. et al., 2002). So we present the electronic nose and tongue systems to supplement human sensory evaluation of tobacco.

The aims of this study include the discrim-

*연락저자 : 305-805 대전광역시 유성구 신성동 302 번지, KT&G 중앙연구원
*Corresponding author : *KT&G Central Research Institute, 302 Shinseong-dong, Yuseong-gu, Daejeon 305-805, Korea*

sensory attributes are correlated with e-instrument's sensors and the evaluations of E-Nose/ination of different tobacco types by the tongue, the analysis of what human the feasibility of the electronic nose and tongue systems for the sensory evaluation. Several studies of using data of tobacco components, sensory evaluation and electronic nose were conducted. Aroma, taste, irritation, and smoke volume of sensory test had high relation to tar, p-cresol threonolatone, levoglucosane, and quinic acid-r-lactone of smoke(Hwang, K.J. et al., 2000). And the E-Nosedata showed high efficiency for discriminant analysis. In study of the electronic nose(AromaScanner), sensor array provides a "fingerprint" of the sample volatiles(Deutsch, L.J., 1996). Application of the electronic nose showed practical analysis example of tobacco discrimination(Robie, D.J., 1997). Combined E-nose (chemFETs) and tongue (SH-SAW devices) system were use to discriminate milk samples. SH-SAW showed excellent discrimination (Sehra, G.S., 2002).

. MATERIALS AND METHODS

Samples

Five different types of Korean domestic tobacco were manufactured into cigarettes as aged burley and not aged, aged flue-cured and not aged and blending types of the four. Sample cigarettes were listed in Table 1.

Sensory evaluation

For this study, panel setup was accomplished by use of same/difference test of two cigarettes over twelve times. And empirical logit value was calculated by same/difference method. Then we selected 10 panelists having value over 1(over 75 % correct). Sensory attributes of tobacco tastes are impact, irritation, bitterness, hay-like, tobacco taste, smoke volume, smoke pungent and mouth clean. Sensory evaluation tests were performed 3 times to each sample. Sensory evaluation method, known as Quantitative Descriptive Analysis (QDA), was adapted to evaluate the perceptual changes which occur during the smoking test. We used the sequential monadic design to obtain the reproducibility in the experiment.

Electronic nose analysis

A FOX4000 electronic nose system was used to analyze and discriminate different tobacco samples in solid form(Alpha M.O.S, Toulouse, France). The system is equipped with 18 gas metal oxide semiconductors(MOS) sensors (designated S01 to S018 different selectivity and sensitivity) that respond to volatile organic compounds(VOCs) characteristic of aromas and odors found in sample gas phase (headspace). Samples of cut tobacco from test cigarettes(500 mg) were introduced into 10 mL vials, sealed(using aluminum cap) and placed a HS100 AutoSampler. Samples were incubated for 30 min at 60 °C(headspace generation) and then volatiles (1000 uL) were transferred automatically to the

Table 1. Sample Lists E-Nose and E-Tongue

E-Nose Samples		E-Tongue Samples	
Sample	Type	Sample	Type
SBB	Not aged burley	A01-A04	Not aged burley
SBA	Aged burley	C09-C12	Aged burley
SFB	Not aged flue-cured	B05-B08	Not aged flue-cured
SFA	Aged flue-cured	D13-D16	Aged flue-cured
		U24, U26, U27	Blending

electronic nose using a gas tight syringe. Inside the system, a constant dry air carrier gas flow(set to 150 mL/min) is used to sweep the gas sample through the 3 sensor chambers. Each sample was analyzed in triplicate - three vials prepared from the same sample lot and a total of 48 were collected in this way(4 types * 4 lots * 3 replicates). Data collection and processing was performed using the AlphaSoft V8 software package(Alpha M.O.S).

Electronic Tongue analysis

A ASTREE electronic tongue system was used to analyze and discriminate different tobacco samples in liquid form(Alpha M.O.S, Toulouse, France). The system is equipped with 7 liquid organic potentiometric sensors(ISFET) that cross selective and partially specific and respond to ionic and non-ionic compounds present in liquid solution samples. Samples were collected tobacco smoke particulate of 20 cigarettes on a Cambridge filter by using an automatic smoking machine and extracted the tobacco smoke particulates in the Cambridge filter with 100 mL of methanol. The sample solutions contain 8-36 mg of nicotine and 80-200 mg of tar(and other unidentified compounds, normally found in tobacco smoke particulate). Sensor array set were YY3225, BA3403, BB3402, CA3508, GA3402, HA2909, JB3508. Sample volume was 100 mL, acquisition time was 2 min, rinsing time was 1 min, sample temperature was room temperature and sample was prepared by dilution 10% in ethanol.

Statistical analysis

We accomplished correlation analysis between sensory evaluation attributes (human data) and individual gas or liquid sensor responses (e-instrument data) by using *STATISTICA* software (StatSoft, Inc., Tulsa, USA). The discrimination of tobacco characteristics by e-instruments was conducted by exploring the data using principal component analysis(PCA) and discriminant factorial analysis(DFA) models drawn from data sets using built-in software package(AlphaSoft V8 for E-Nose and AstreeSoft V2 for E-Tongue).

RESULTS AND DISUSSION

Electronic nose and sensory analysis

In E-Nose analysis, impact, bitterness, irritation, smoke volume and smoke pungent of human sensory attributes were specifically correlated with data from the several clustered E-Nose sensors(Table 2). PCA plot by E-Nose showed that aged tobacco and not aged were discriminated and DFA plot showed that three groups(aged burley, not aged burley and flue-cured) were discriminated(Figure 1).

Individual E-Nose gas sensors showed good correlation with sensory attribute impact(S01: -0.59), bitterness(S15: -0.80), irritation(S15: -0.81), smoke volume(S09: -0.80) and smoke pungent(S12: -0.80). Also smoke volume and irritation have linear relationship(Hwang, K.J. et al., 2000). Human percept like hay-like, tobacco taste and mouth clean attributes very well but e-instruments are not, because e-instruments sensors are based on human sense organs and do not understand definition of these human attributes.

Electronic tongue and sensory analysis

We found that bitterness, irritation, and smoke pungent of human sensory attributes were correlated with data from the E-Tongue sensors(Table 3).

E-Tongue sensors were reacted to sensory attributes bitterness(T_Sensor2: -0.76), irritation (-0.72), smoke pungent(-0.78). These reason is that taste organ of human perceives like bitterness and pungent very well.

PCA plot by the E-Tongue showed that burley tobaccos(A & C) were separated from flue-cured tobacco(B & D). Also aged burley(C) and aged flue-cured(D) were very well discriminated(Fig. 2).

In order to identify the blending tobaccos(U),

Table 2. Correlation data of sensory attributes and E-Nose sensors($p < .10$)

E-Nose	Impact	Bitterness	Hay-like	Tobacco taste	Irritation	Smoke volume	Smoke pungent	Mouth clean
S01	-0.59	-0.75	-0.03	-0.12	-0.77	-0.76	-0.69	0.53
S02	0.56	0.69	0.04	0.12	0.73	0.77	0.68	-0.5
S03	0.57	0.71	0.03	0.12	0.75	0.78	0.70	-0.5
S04	0.57	0.69	0.04	0.12	0.73	0.77	0.68	-0.5
S05	0.56	0.70	0.05	0.11	0.74	0.78	0.70	-0.49
S06	0.57	0.70	0.05	0.12	0.74	0.78	0.70	-0.5
S07	-0.53	-0.76	0.03	-0.05	-0.80	-0.75	-0.79	0.47
S08	-0.54	-0.73	0.02	-0.08	-0.78	-0.77	-0.78	0.47
S09	-0.51	-0.64	0.00	-0.09	-0.72	-0.80	-0.77	0.42
S10	-0.54	-0.73	0.01	-0.08	-0.78	-0.78	-0.78	0.47
S11	-0.54	-0.75	0.04	-0.05	-0.79	-0.75	-0.79	0.47
S12	-0.52	-0.77	0.05	-0.07	-0.80	-0.75	-0.80	0.48
S13	-0.53	-0.76	0.05	-0.03	-0.80	-0.72	-0.79	0.47
S14	-0.54	-0.72	0.01	-0.07	-0.77	-0.77	-0.78	0.46
S15	-0.54	-0.80	0.01	-0.08	-0.81	-0.74	-0.77	0.52
S16	-0.4	-0.44	0	-0.07	-0.58	-0.76	-0.72	0.29
S17	-0.35	-0.35	0	-0.05	-0.51	-0.73	-0.7	0.22
S18	-0.37	-0.38	0	-0.04	-0.53	-0.74	-0.71	0.23

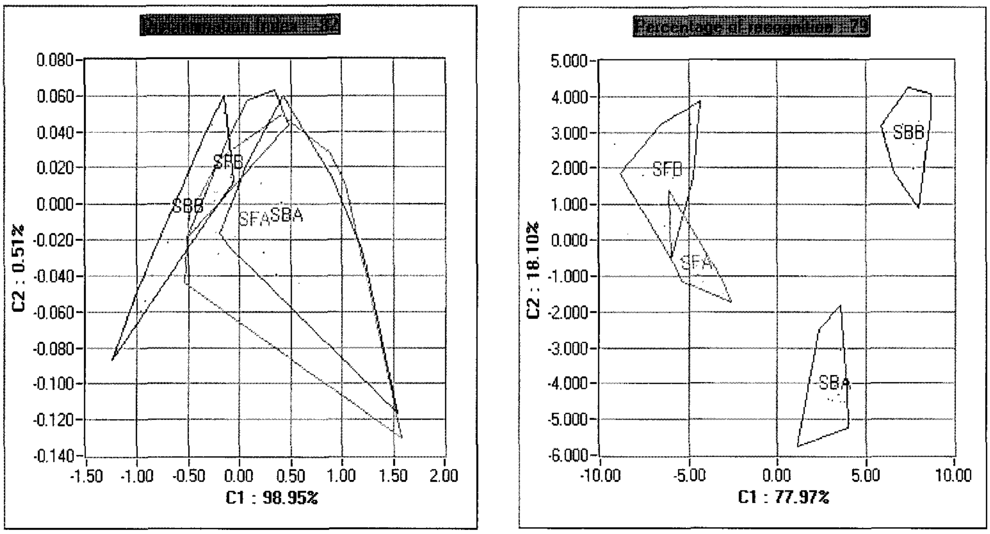

Fig. 1. PCA(left) and DFA(right) plots of four kind tobaccos(not aged burley, aged burley, not aged flue-cured and aged flue-cured) by the E-Nose analysis. PCA plot showed discrimination of aged tobaccos(SFA, SBA) and not aged(SFB, SBA). DFA plot distinguished the burley tobaccos(SBA, SBB) and the flue-cured tobaccos(SFA, SFB), also not aged burley(SBB) and aged burley(SBA).

Table 3. Correlation of the sensory attributes and the E-Tongue sensors(p < .10)

E-Tongue sensors	Impact	Bitterness	Hay-like	Tobacco taste	Irritation	Smoke volume	Smoke pungent	Mouth clean
T_Sensor1(YY3225)	0.08	-0.62	0.01	0.09	-0.53	-0.35	-0.70	0.41
T_Sensor2(BA3403)	-0.32	-0.76	-0.01	-0.06	-0.72	-0.67	-0.78	0.49
T_Sensor3(BB3402)	0.08	-0.63	0.00	0.08	-0.53	-0.35	-0.70	0.41
T_Sensor4(CA3508)	-0.04	0.65	0.04	-0.08	0.55	0.38	0.71	-0.41
T_Sensor5(GA3402)	0.08	-0.62	0.01	0.09	-0.53	-0.35	-0.70	0.41
T_Sensor6(HA2909)	-0.06	0.64	0.01	-0.07	0.54	0.36	0.69	-0.42
T_Sensor7(JB3508)	-0.08	0.63	0.00	-0.08	0.53	0.35	0.70	-0.41

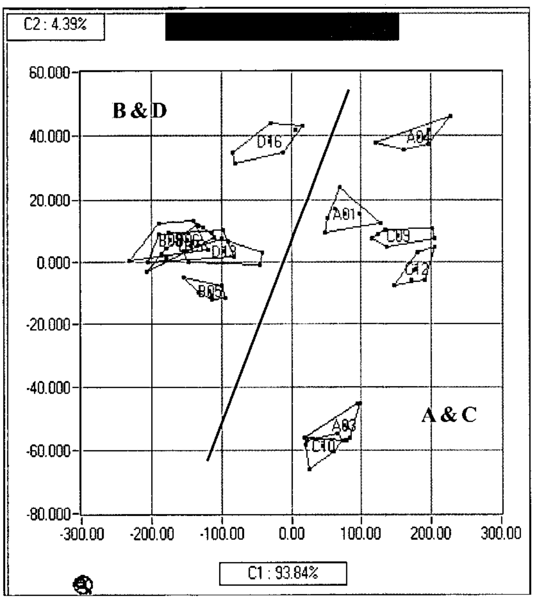

Fig. 2. This PCA allows to seeing that we discriminate the different samples. Tobacco B and D are on the left part of the graph and tobacco A and C on the right part.

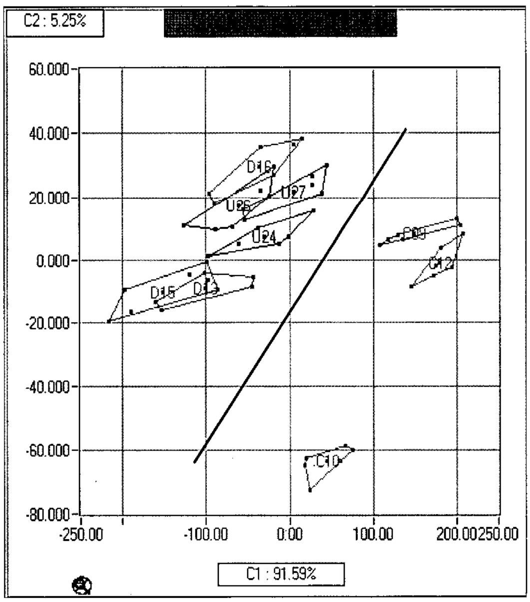

Fig. 3. D samples on the left part of the graph and C samples on the right part. On this PCA, the blending tobacco samples(U) considered is closed to the D group.

we have made a DFA with the samples situated in the defined area(Fig. 4). U samples were separated from others(C, D), but each blending tobacco was not separated among blending tobaccos.

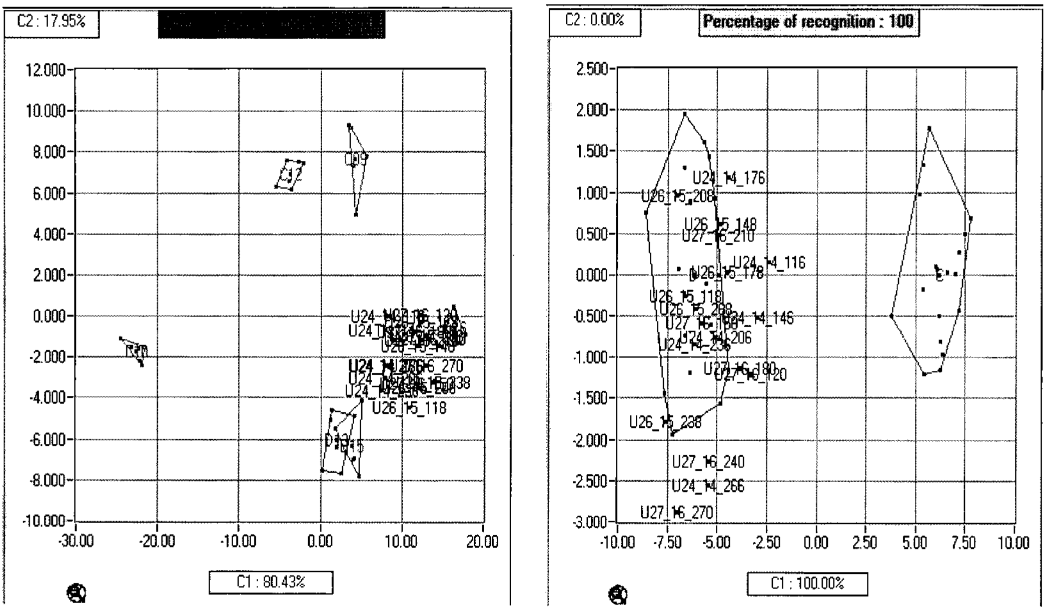

Fig. 4. Discriminant Factorial Analysis(DFA) with C, D and U samples.

CONCLUSIONS

Data from the several clustered E-Nose sensors were correlated with impact, bitterness, irritation, smoke volume and smoke pungent of human sensory attributes. Also the electronic tongue sensed impact, irritation, and smoke pungent. In discrimination analysis, the E-Nose distinguished two group(aged tobacco and not aged) by PCA plot and three groups(aged burley, not aged burley and flue-cured) by DFA plot and the E-Tongue showed that burley tobacco was separated from flue-cured tobacco, and aged burley and aged flue-cured are very well distinguished. We assumed that among the human sensory attributes, impact, irritation, smoke volume and smoke pungent were very important attributes. The E-Nose/tongue sensors were sensitive to those attributes. So the electronic nose and tongue can be used to supplement human sensory evaluation of complex cigarettes for reliability and reproducibility. Future work is to finding the practical methods of testing directly the smoke from cigarette by the e-instruments, then the sensory evaluation of tobacco will be simple and saving cost and reducing time.

Acknowledgments

Technical work was partly supported by Alpha-M.O.S.(Toulouse, France).

REFERENCES

Chmielewski, J. and Kazio, J. (2002) Electronic nose: a useful too for aroma change monitoring. *ISEON'02* : 299-302.

Deutsch, L.J. and Shimanski, C.A. (1996) Electronic aroma analysis. *CORESTA*.

Furlong, C., Farmer, L.J., Hagan, T.D.J, Cheung, C. Stewart, J.R and Bailleul, A. (2002) Determination of nectarine quality using an electronic nose and a preconcentration system to complement sensory panel, GC-MS and GC-odour analysis. *ISOEN'02* : 58-63.

Hwang, K.J., Rhee, M.S. and Ra, D.Y. (2000) Statistical approach for development of objective evaluation method on tobacco smoke. *CORESTA.*

Robie, D.J. (1997) Comparison of two electronic noses: three tobacco applications. *Seminars in Food Analysis* 2 : 247-256.

Sehra, G.S. Convington, J. Cole, M. and Gardner, J.W. (2002) Combined Electronic nose/ tongue system for liquid analysis. *ISOEN'02* p. 256-262.

Shon, H.J. and Lee, S.G. (2003) Availability of electronic nose technology for the discrim-ination of ginseng origins. *ISOEN'03* p. 99-102