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Gaseous Aliphatic Aldehydes in Smoke from Burning Raw Materials of Chinese Joss Sticks

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Burning Chinese joss sticks for worship rituals is a Chinese daily routine. However, it is suspected to be a factor in the development of certain diseases. Contact dermatitis due to musk ambrette exposure in incense has been reported by Hayakwa(Hayakwa et al, 1987 a; Hayakwa et al, 1987 b). Epidemiological studies have correlated contact dermatitis with a high risk of childhood leukemia (Lowergard et al, 1987), childhood brain tumor (Preston-Martin et al, 1982), and nasopharyngeal cancer (Chen et al, 1987; Yu et al, 1990). Correlation studies of lung cancer and incense smoke have been inconclusives (MacLennan et al, 1977; Chen et al, 1990). Ames identified the mutagenic effect of the smoke from burning Chinese incense (Rasmussen, 1987). The smoke had been proved to contain polycyclic aromatic hydrocarbons (PAHs), aromatic aldehydes and aliphatic aldehydes (Schoenotol and Gibbard, 1967; Lin and Wang, 1994). This study was carried out in order to look into the aliphatic aldehydes content in smoke released from burning the various raw materials of which a Chinese joss stick is composed,

MATERIALS AND METHODS

A local manufacturer provided a kind of Chinese joss stick with dye coated on. The joss stick is composed of incense powder and a bamboo stick. The powder is a mixture of 15 different varieties of dried and ground vegetation. Table 1 shows their names and percentages in the composition. The local manufacturer also offered the fifteen raw materials. Each was ground by a grinder (Braun 2k 100, Multiquicks System 100, Germany), and sifted by a sieve with 60/60 mesh. Then powder was pressed into a mold with 3.5 cm height and 1.3 cm diameter forming a cone. The cone of material was put into a stainless steel planchette with fringe, weighted and placed in a burning chamber. The burning chamber (68 X 48 X 44 cm^3) was constructed by using polypropylene. The chamber was purged for about 50 minutes with purified air at a flow rate of 30 L/min and humidity of 50±3% ,

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Table 1. Composition of a joss stick

Component	Weight percentage
Mixed powder of	21
(1) *Glycyrrhiza uralensis* Fisch.	
(2) *Cinnamomun cassia* Bl.	
(3) *Ocimum basilicum* L.	
(4) *Nardostachys chinensis* Basta*l*.	
(5) *Foeniculum vulgare* Mill.	
(6) *Rheum officinale* Baill.	
(7) *Radix Aucklandia*	
(8) *Asarum sieboldii* Miq.	
(9) *Magnolia liliflora* Desr.	
(10) *Eugenia caryophyllata* Thumb.	
Plain powder	
(11) *Juniperus chinensis* L. var. Kaizuca Hort.	1
(12) *Lysimachia foenum-graecum*	1
(13) *Liquidambar formosana* Hance.	2
(14) *Santalum album* L.	32
(15) *Machilus nanmu* Hemsl.	10
Stem	
(16) Bamboo stick	33

regulated by a Flow Temperature-Humidity Control System (Model HCS 301, Miller Nelson Research). Then the inlet and outlet of the chamber were closed and the cone of material was ignited by a nickel-chrome wire controlled by a voltage regulator. It took about 12±3 minutes to burn each cone. Sampling began right after the end of burning, by using a 2,4-dinitrophenyl-hydrazine coated Sep-Pak DNPH silica cartridge (Part No.37500, Millipore) in 2 L/min for 1 min. The Sep-Pak was eluted by 5 mL acetonitrile (BDH, Hipersalv, England). The high performance liquid chromatograph (HPLC, Model 590, Waters, USA) equipped with the U.V. detector set at λ max 254 nm was utilized to determine the derivatives. A series of standard solution of aldehyde 2,4-dinitrophenyl-hydrazones was prepared from a stock solution formed by spiking a mixed aldehydes standard solution (aldehydes standard solution kit, TK-151, Alltech) onto the Sep-Pak and eluting the Sep-Pak with 5 mL acetonitrile. A quantified 4-fluorobenzonitrile (46680, Fluka) in acetonitrile (0.134g/10 mL) served as an internal standard. An aliquot 15 µL sample was injected into the HPLC with a column of Nova-Pak C_{18} (150 mm X 3.9mm) and a 0.1 mL/min flow rate of solvent (acetonitrile/H_2O; 60/40 V/V). The peak area ratio and retention time for each derivative of aldehyde relative to the internal standard was calculated when each sample was quantified. The burning weight for each raw material was obtained by substracting the residue weight from the initial weight. The yield rate

of each aldehyde from burning each raw material was expressed in mg per gram of burning weight. The smoke generated from burning a joss stick was also analyzed for comparison. The effects of ventilation and burning rate (g/min) on the yields of aliphatic aldehydes were also demonstrated in the laboratory

RESULTS AND DISCUSSION

Table 2 shows the yields of aliphatic aldehydes when burning the component materials of a joss stick. Formaldehyde, acetaldehyde, acrolein, propanal and butanal existed in the smoke. The smoke from burning a joss stick with a bamboostick, contained a higher amount of aliphatic aldehydes than that from an incense powder mixture without bamboo. This demonstrates that bamboo is a major source of aliphatic aldehydes, especially formaldehyde, released during burning.

Table 2. Generation of aliphatic aldehydes from burning a joss stick, mixed incense powder, and a bamboo stick

	Aldehyde yield from burning material at unventilated conditions, mg aldehyde / g material burned		
Aldehydes	Joss stick	Mixed incense powder*	Bamboo stick**
Formaldehyde	6.1	2.3	7.5
Acetaldehyde	3.1	2.1	4.7
Acrolein	2.7	1.5	2.4
Propanal	0.8	0.4	0.7
Butanal	0.5	0.6	0.3

* The powder scraped from a joss stick

** A bare bamboo stick without incense powder

Table 3 designates the yields of alphatic aldehydes when burning one gram of vegetative component. The smoke from burning Juniperus and Santalum abounded in formaldehyde. Table 4 estimates the percentage contribution of the various components in a joss stick to the formation of aliphatic aldehydes. The highest contributers to formaldehyde release were bamboo 51% and Santalum 42%.

Table 5 gives the generation data of aliphatic aldehydes from burning raw material in ventilated conditions. The aldehydes yields obviously are reduced when the material is burned under ventilated conditions with a flow rate of 5 L/min.

Table 6 demonstrates that the yields of aliphatics aldehydes only slightly reduce when the burning rate of Juniper is changed from 0.02 g/min to 0.05 g/min.

Table 3. Generation of aliphatic aldehydes from burning the raw materials of a joss stick

	Aldehyde yield from burning material at unventilated conditions, mg aldehyde / g material burned					
Raw material	Formal. *	Acetal.*	Acrolein	Propanal	Butanal	Total
Juniperus	7.3	2 2	1.3	0.3	0.1	11.1
Santalum	6.4	2.2	1.0	0.3	0.8	10.7
Machilus	1.4	2.7	2.3	0.7	0 8	7.9
Nardostachys	0.8	2.2	1.8	0.7	1.5	6.9
Liquidambar	2.0	1.5	1.3	0.2	0.3	5.3
Ocimum	0.1	2.7	1.6	0.6	17	6.8
Glycyrrhiza	0.2	2.4	1.8	0.5	1.3	6.2
Asarum	0.8	1.7	1.3	0.6	1.0	5.4
Magnalia	0 8	2.0	1.3	0.3	0.5	4.9
Lysimachia	0.8	1.8	1.3	0.8	0 2	4.9
Foeniculum	0.1	2.1	1.3	0.5	13	5.3
Rheum	0.4	1.1	1.8	0.2	0.4	4.0
Cinnamomun	0.3	1.2	1.3	0.3	0.7	3.8
Eugenia	0.2	0.9	1.2	0.3	0.5	3.0

* Formal. : Formaldehyde ; Acetal. :Acetaldehyde

Table 4. Expected contribution to the formation of aliphatic aldehydes by components of a joss stick

Component name	Weight percentage	Expected contribution** (%)				
	Pi (%)	Formal.***	Acetal.***	Acrolein	Propanal	Butanal
Bamboo	33	50.6	53.1	46.5	47.0	7.7
Santalum	32	42.1	23.4	19.6	19.5	45.4
Mixedpowder*	2 1	1.9	12.2	18.0	174	32.3
Machilus	10	2.8	8.9	13.0	12.8	13.1
Liquidambar	2	0.8	0.9	1.3	0.9	0.8
Juniperus	1	1.6	0.8	0.8	0.7	0.3
Lysimachia	1	0.2	0.7	0.8	1.7	0.4

* Refer to Table 1

** [(Pi X Gi)/ (Pi X Gi)] X 100

Where, Gi is the generation rate shown as in Table 2 and Table 3

*** Formal. : Formaldehyde ; Acetal. : Acetaldehyde

Table 5. Generation of aliphatic aldehydes from burning material under ventilated conditions and unventilated conditions

Condition with material	Aldehyde yield from burning material at controlled conditions, mg aldehyde / g material burned					
	Formal.*	Acetal.*	Acrolein	Propanal	Butanal	Total
Without ventilation						
Joss stick	6.1	3.1	2.7	0.8	0 5	13.1
Bamboo	7.5	4.7	2.4	0.7	0.3	15.6
Machilus	1.4	2.7	2.3	0.7	0.8	7.9
Santalum	6.4	2.2	1.0	0.3	0 8	10.7
Foeniculum	0.1	2.1	1.3	0.5	1.3	5.3
Cinnamomun	0.3	1.2	1.3	0.3	0.7	3.8
With ventilation (Flow rate 5 L/min)						
Joss stick	1.8	1.2	1.3	0.4	0.8	5.4
Bamboo	4.6	3.4	2.0	0.5	0 1	10.6
Machilus	0.6	1.2	1.1	0.1	0.1	3.2
Santalum	1.8	1.1	0.7	0.2	0.4	4.1
Foeniculum	0.1	2.5	1.2	0.3	0 1	4.2
Cinnamomun	0.3	0.8	0 7	0.2	0.1	2.1

* Formal. : Formaldehyde ; Acetal. : Acetaldehyde

Table 6. Relationship between aliphatic aldehyde yields and the burning rate of Juniperus

Burning rate	Aldehyde yield from burning material at unventilated conditions, mg aldehyde / g material burned					
(g/min)	Formal.**	Acetal.**	Acrolein	Propanal	Butanal	Total
0.02	7.5	2.3	1.7	0.4	0.3	12.3
0.04	6.9	2 4	12	0.4	0.1	10.9
0.05	7.4	1.9	0.9	0.2	ND*	10.4

* ND, non-detectable

** Formal. : Formaldehyde ; Acetal. : Acetaldehyde

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