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Development of Oil Fume Adsorbing Material of Food Industry from Fermentation Residue – Distillery Grains

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This study used fermentation waste–Sorghum Distillery Residue (SDR) as the precursor to prepare Sorghum Distillery Residue Activated Carbons (SDRACs) by physical activation with steam, in order to investigate the feasibility evaluation of SDRACs paperboard (SDRACP) with thermal absorption as an oil fume absorption filter material. The SDRACP with 360 g/m^2 of based weight at 0, 10 and 40% of SDRACs was made by wood pulps with 20% Nadelholz unbleached kraft pulps and 80% Laubholz unbleached kraft pulps. The oil fume absorption from the SDRACPs was about 0.0442–0.0568 g/cm^2 till the end of heating procedure at 310 min, respectively. The preliminary safety evaluation by using the Ames test for the oil fume compounds extracting with methanol from SDRACP at the concentration over 0.100 mg/plate had cytotoxicity toward *Salmonella typhimurium* TA98 and TA100 with S9 mix or without S9. For the mutagenicity, the mutagenicity ratio at 0.050 and 0.010 mg/plate of methanol extracts toward *Salmonella typhimurium* TA98 and TA100 with or without S9 was over 2, indicating the SDRACs had a higher mutagenicity. The GC–MS analysis for the oil fume dissolve hexane portion from SDRACP showed that the trans–trans–2,4–decadienal (t–t–2,4–DDE) was one of mutagenicity compounds from peanut oils. The SDRACP, developing from the study, can be a reference to as the filter materials of oil fume in food industry.

Key words: Sorghum Distillery Residue (SDR), Sorghum Distillery Activated Carbons Paperboard (SDRACP), Thermal Absorption, Oil Fume, Ames test

INTRODUCTION

The environmental protection programs, the "Resource Recovery Program" and the "Full Waste Classification and Zero Waste Group Action Project", have recently been executed in Taiwan. Sorghum distillery residue (SDR), one residual product brewed from sorghum liquor, belongs to fermentation wastes in food industries and is about 135,600 MT in Taiwan (Environmental Protection Administration, 2016). Research development of SDR, includes soil improvement and crop nutrition, compost materials, biotransformation using fungus, extracting antioxidants, functional application of extracts, production of ethanol biomass, feed improvement (Perdih *et al*., 1991; Lee and Pan, 2003; Bustamante *et al*., 2007; Esperanza *et al*., 2007; Lafka *et al*., 2007; Bustamante *et al*., 2009; Su *et al*., 2010; Aliakbarian *et al*., 2012; Anandan *et al*., 2012; Nguyen Thi, 2012; Wang, 2012; Paradelo *et al*., 2013), and so on. These reports have only been in the research stage. However, the wastes, SDR, as the resources can help social and economic development, if they can be reused and/or regenerated, and solve the waste problem.

The previous study (Lin *et al*., 2015a and 2015b) reported that the SDR can be prepared into activated carbon (AC) with multiple mesoporous, and used as functional water purifying material. The hollow structure and good absorption of AC can provide a functional adsorbent material, especially for a moisture–proof material for food use, such as: placed in salt, pepper or flavoring jars to keep them dry and prevent deliquescence and foreign flavor, or as a treatment process, e.g. conserving medical drugs (Liou, 2012; Lin, *et al*., 2014a; Lin, *et al*., 2014b). Based on the distribution of pores in different diameters, pore structure and a high specific surface area, the specific surface area of AC, it is more applicable to adsorbing organic pollutants because of its high specific surface area (Kienle and Bader, 1990).

It is well known that lung cancer is attributed to kitchen oil fumes and the key factors in the steadily climbing number of lung cancer cases (Ministry of Health and Welfare, 2015; Taiwan Clinical Oncology Research Foundation, 2011). Lee *et al*. (2007) report that exposure to kitchen oil fume can be correlated with the survival and proliferation of pulmonary adenocarcinoma cells, as oil fume particles are 0.15–0.56 μm. In addition, long–term exposure to cooking oil fume environments is significantly related to lung cancer and engaging in the cooking process without a range hood has higher correlation (Wu, 2004; Wu and Pan, 2014). According to the findings of cooking exposure, the lung cancer risk of a kitchen without a range hood is higher than that with a range hood by 3.7–4.8 times. The high lung cancer risk; therefore, is highly correlated with cooking oil fume (Ko and Lee, 1997; Lee and Ko, 2000).

Therefore, this study prepared SDR into SDRAC that made with the wood pulp into the different proportions of SDRAC Paperboard (SDRACP), in order to as the value–added material of absorbability for the oil

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fume derived from the adsorbed oil by high temperature heating in food industry. This study intended to use SDRACP as the oil fume absorption filter material in oil fume kitchen environments. The oil fume absorbed by SDRACP, and then extracted with methanol. The oil fume methanol extracts were examined for Ames test, including cytotoxicity and mutagenicity. The carcinogenicity for the human body was evaluated initially. The extracts were analyzed by GC–MS to realize some of the absorbed toxic substances.

MATERIALS AND METHODS

Specimens

Precursor

Sorghum distillery residue (SDR) as the precursor was obtained from Kinmen Kaoliang Liquor INC, Taiwan. The SDR was washed and had a moisture content of less than 15.0% after being air–dried at ambient temperatures.

Wood pulp

Nadelholz unbleached kraft pulps (NUKP) and Laubholz unbleached kraft pulps (LUKP), supplied from Cheng Loong Pulp, Taiwan.

Peanut oil

It was bought from the Chiayi City Hsinchang Cooking Oil Co, Taiwan.

Test strains

Salmonella typhimurium (*S. typhimurium*), including TA98 and TA100, was bought from the Bioresource Collection and Research Center, Food Industry Research and Development Institute, Taiwan

Rat liver mixture

The rat liver mixture (S9) (Organ Teknika Co., Switzerland) was prepared from Sprague–Dawley male rats treated with Aroclor 1254.

Experimental methods

Preparation of Sorghum Distillery Residue Activated Carbons (SDRACs)

Stage I preparing 20 g SDR by absolute dry weight was carbonized for the first stage at nitrogen flow 200 mL/min, carbonization temperature of 800 and 850°C, and heating rate 10°C/min. Stage Ⅱ activation was implemented at steam flow 90, 120 and 150 mL/h and activation temperature of 800 and 850°C for 60 min. Stage Ⅲ was cooled at nitrogen flow 200 mL/min for 4 h, and removed at normal temperature to obtain SDRACs. The yield and iodine value of SDRACs was 10.63 to 26.07% and 548 to 770 mg/g. The BET specific surface area was 502.7 to 530.1 m^2/g, the average pore diameter ranged from 2.89 to 3.18 nm. The nitrogen adsorption–desorption isotherms of the SDRAC were classified as Type IV, indicating the presence of microporous and mesoporous structures, according to the Bruauer, Deming, Deming and Teller (BDDT) Classification, and were H3 type hysteresis loops for most of the mesoporous structures in accordance with the International Union of Pure and Applied Chemistry (IUPAC) (Lin *et al*., 2015a and 2015b). The SDRACs used in this study were prepared from the conditions of 850°C of carbonization temperature with heating rate 10°C/min at nitrogen flow 200 mL/min and 850°C of activation temperature at steam flow 90 mL/h.

*Sorghum Distillery Residue Activated Carbons paperboard (SDRACP) making metho*d

Referring to the making method of Lin *et al*. (2015a), the basis weight of SDRACP was 360 g/m^2, NUKP 20% and LUKP 80% were mixed using the beater method, mixed with 0, 10, and 40% SDRACs by weight with a cylinder paper machine, referring to the CNS11212 method of making handmade paper for physical testing. The SDRACP codes are 10 or 40% SDRACP, and the control group is PBO (without SDRACs).

Determination of moisture content of SDRACP

The moisture content in all SDRACPs was determined by referring to CNS 3086 method of test for determination of moisture content in pulp, paper and board (Oven–drying method). The air–dried moisture content of PBO was about 8.59%, while that of SDRACPs was 8.12–8.37%. According to Duncan's multiple range test analysis, there was no significant difference between PBO and the various SDRACPs.

Smoke point determination

Referring to the measuring method of the American Oil Chemists' Society (AOCS) (2017), in an unventilated and light–proof environment, the oil (peanut oil) was heated and observed visually, and the temperature at which the peanut oil emits thin fume was the smoke point.

Oil fume absorption test for SDRACP

The measuring methods are referred to Lin *et al*. (2018). The computing equation is oil fume absorption (g/cm^2) = (SDRACP or PBO absorption weight – air–dried weight of SDRACP or PBO) / (SDRACP or PBO absorption area). For the SDRACP reaches absorption saturation, each absorbance point was calculated and tested by Duncan's multiple range test analysis.

Collection and compounds extraction of oil fume

The PBO and SDRACP are collected after 10 min absorption of oil fume (Ichikawa, 2012; Lin *et al*., 2018). The compounds extraction of oil fume is referred to (Wu and Yen, 2000; Lee *et al*., 2007). The PBO and various SDRACPs collected from oil fume were extracted in the dark by 200 mL methanol at room temperature, and shaken in a digital rotary shaker (Orbital shaker, YIH DER TS–585D) at 100 rpm/min during extraction. Using methanol as the solvent to extract peanut oil fume results in the maximum yield (Wu, 1997). The methanol in the extraction liquid was concentrated to dry by a rotary decompression concentrator (Rotatory vacuum evaporator, Heidolph LABOROTA 4000) at 40°C of temperature. The methanol extraction liquid was obtained after 24 h, and the end products were methanol extracts.

Mutagenicity of oil fume methanol extracts
Cytotoxicity

Referring to the experimental method of Lin *et al.* (2014a and 2014b) and Lin *et al.* (2018), The colony (bacterial) count was calculated; if the bacterial count of the test group (including with or without S9 mix) was greater than the bacterial count of the control group by 80% (the bacterial count rate, Survival; %), there was no cytotoxicity Ames *et al.* (1975). The survival of cytotoxicity is calculated as follows:

Survival (%) = (the bacterial count of test group / the bacterial count of control group) * 100

Mutagenicity

Referring to the experimental method of Lin *et al.* (2014a and 2014b) and Lin *et al.* (2018), the colony count of the TA98 and TA100 test groups is greater than that for the control group by more than two times, the specimen has mutagenicity, meaning the Mutagenicity ratio = induced revertants per plate/spontaneous revertants per plate (Blank).

Oil fume extracts compounds analysis

Referring to the method of Ron and Louisa (1972) and Lin *et al.* (2018), the oil fume extracts compounds were compared with the standard mass spectrum, and the database is searched via Wiley/NBS, Nation Institute of Standard and Technology (NIST), and combined with the Kovat's index (KI) value for comparative analysis and confirmation. The compositions quantification calculated the content of various compounds according to the gas phase mass spectrogram peak area.

Statistical analysis

The test results are represented by a mean (standard deviation), and the control group and test group are compared by Duncan's Analysis. If the ρ value is smaller than 0.05, meaning a significant difference between the test group and the control group, it is represented by different superscript upper case letters.

RESULTS AND DISCUSSION

Oil fume absorbability

Smoke point

The smoke point of the peanut oil was 105±1°C. The oil products with a smoke point lower than 170°C is classified as low smoke point oil and fat, which is only suitable for cold use, dressing with sauce, and boiling. The oil for deep frying must have high smoke point oil and fat at above 200°C (Chen, 2014).

Oil fume absorption by SDRACP

The absorption results of peanut oil fumes at the smoke points of SDRACPs and PBO are shown in Fig. 1. The oil fume absorption of various SDRACPs increased with the proportions of SDRACs. The oil fume absorption of PBO, 10% SDRACP, and 40% SDRACP was 0.0419, 0.0494, and 0.0553 g/cm^2 when they reached their absorption saturations at 200, 240, and 240 min. The oil fume absorption of them till the end of heating procedure at 310 min was 0.0442, 0.0503 and 0.0568 g/cm^2, respectively.

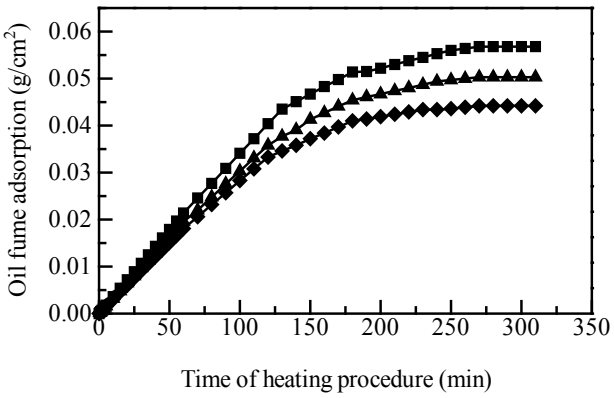

Fig. 1. Oil fume absorption from the smoke point of peanut oil for various SDRACPs
Legends —◆— : PBO; —▲— : 10% SDRACP; —■— : 40% SDRACP

Yield of methanol extracts

The yields of the methanol solvent extraction concentrations for PBO, 10% SDRACP, and 40% SDRACP absorbed peanut oil fume were 0.41, 0.98, and 1.11%, respectively (Table 1). The yield increased with the proportions of SDRACs. PBO was significantly different from 10 and 40% SDRACP in accordance with Duncan's multiple range test analysis.

Table 1. Yield of methanol extracts of various SDRACPs with peanut oil fume Unit: %

Extracts	Yield
Oil fume in PBO[1)]	0.41 ± 0.00[a 2)]
Oil fume in 10% SDRACP	0.91 ± 0.01[b]
Oil fume in 40% SDRACP	1.11 ± 0.04[c]

[1)] PBO: without SDRACs; 10 and 40% SDRACP was mixed with 10 and 40% SDRACs by weight
[2)] Mean ± standard deviation; separation within lines by Duncan's multiple range tests at 5% significant level

Mutagenicity of oil fume methanol extracts

Cytotoxicity

The bacterial survival rate (Survival, %) of the specimen after testing is higher than the blank group by over 80%, meaning the specimen is non–toxic to cells (no cytotoxicity) (Waleh *et al.*, 1982). The cytotoxicity of methanol extracts from the peanut oil fume absorbed by each type of SDRACP for *S. typhimurium* TA98 and TA100 strains are shown in Table 2.

The bacterial count of the blank group (Blank) of *S. typhimurium* TA98 without rat liver mixture (–S9) was 2837, and that of TA100 was 2758. The bacterial count of Blank of *S. typhimurium* TA98 with rat liver mixture (+S9) was 2897, and that of *S. typhimurium* TA100

was 2866. The *S. typhimurium* TA98 (–S9 or +S9) and TA100 (–S9 or +S9) bacterial counts of the methanol extracts of PBO, 10% SDRACP, and 40% SDRACP at test concentrations of 0.010 and 0.050 mg/plate, were 2718–2851 and 2674–2957 cfu/plate, respectively. The results show that the *S. typhimurium* TA98 and TA100 bacterial survival rates of the methanol extracts at concentrations of 0.010 and 0.050 mg/plate, with or without S9, are higher than 80%, representing no cytotoxicity. However, Survival of the *S. typhimurium* TA98 (–S9 and +S9) and TA100 (–S9 and +S9) of the methanol extracts of 10% SDRACP, and 40% SDRACP at a test concentration of 0.100 mg/plate were 47–50% and 45–57%, representing cytotoxicity with cells (Waleh *et al.*, 1982). It is suggested that the methanol extracts at concentrations lower than 0.050 mg/plate have no cytotoxic reaction with *S. typhimurium* TA98 (±S9) or TA100 (±S9), the which can be used for mutagenicity testing.

Mutagenicity

Table 3 shows the mutagenicity results of methanol extracts from peanut oil fume, as absorbed by different proportions of SDRACPs at concentrations lower than 0.050 mg/plate for *S. typhimurium* TA98 and TA100

Table 2. Toxicity of methanol extracts from various SDRACPs with peanut oil fume toward *Salmonella typhimurium* TA98, TA100 with or without S9 mixture

Specimen	Dose (mg/plate)	–S9				+S9			
		TA98 (cfu/plate)	Survival[4] (%)	TA100 (cfu/plate)	Survival (%)	TA98 (cfu/plate)	Survival (%)	TA100 (cfu/plate)	Survival (%)
Blank[1]	0	2837 ± 89[3]	100	2758 ± 77	100	2897 ± 104	100	2866 ± 86	100
PBO[2]	0.010	2838 ± 109	100	2674 ± 65	97	2812 ± 41	97	2871 ± 20	100
	0.050	2774 ± 84	98	2768 ± 75	100	2801 ± 109	97	2850 ± 79	99
	0.100	1337 ± 49	47	1513 ± 131	55	1441 ± 111	50	1634 ± 119	57
10% SDRACP	0.010	2742 ± 115	97	2768 ± 42	100	2851 ± 92	98	2957 ± 80	103
	0.050	2781 ± 96	98	2808 ± 33	102	2718 ± 62	94	2929 ± 14	102
	0.100	1387 ± 93	49	1251 ± 14	45	1402 ± 137	48	1564 ± 69	55
40% SDRACP	0.010	2849 ± 96	100	2751 ± 61	100	2782 ± 34	96	2943 ± 66	103
	0.050	2743 ± 33	97	2680 ± 26	97	2797 ± 103	97	2918 ± 53	102
	0.100	1384 ± 85	49	1384 ± 107	50	1452 ± 67	50	1471 ± 171	51

[1] Blank: blank group
[2] Abbreviation is the same as Table 1
[3] Mean ± standard deviation
[4] Survival (%) = (Colony number of specimen/ Colony number of blank)*100

Table 3. Mutagenicity of methanol extracts from various SDRACPs with peanut oil fume toward *Salmonella typhimurium* TA98, TA100 with or without S9 mixture

Specimen	Dose (mg/plate)	–S9				+S9			
		TA98 (revertants/ plate)	Mutagenicity ratio[4]	TA100 (revertants/ plate)	Mutagenicity ratio	TA98 (revertants/ plate)	Mutagenicity ratio	TA100 (revertants/ plate)	Mutagenicity ratio
Blank[1]	0	51 ± 2^{aA3}	1.00	151 ± 7^{aB}	1.00	48 ± 1^{aA}	1.00	167 ± 3^{aC}	1.00
PBO[2]	0.005	58 ± 4^{bA}	1.14	153 ± 3^{aB}	1.01	51 ± 3^{aA}	1.07	169 ± 5^{aC}	1.01
	0.010	78 ± 9^{cA}	1.53	188 ± 9^{cB}	1.24	84 ± 6^{bA}	1.76	570 ± 11^{cC}	3.41
	0.050	860 ± 23^{eA}	16.87	1279 ± 14^{eB}	8.47	889 ± 34^{dA}	18.51	1381 ± 19^{dC}	8.27
SDRACP–S10	0.005	52 ± 5^{abA}	1.02	155 ± 2^{aB}	1.02	54 ± 6^{aA}	1.12	174 ± 5^{aC}	1.04
	0.010	75 ± 5^{cA}	1.48	186 ± 8^{bcB}	1.23	83 ± 5^{bA}	1.72	501 ± 21^{bC}	3.00
	0.050	790 ± 17^{dA}	15.49	1273 ± 73^{eB}	8.43	812 ± 28^{cA}	16.92	1435 ± 73^{dC}	8.59
SDRACP–S40	0.005	56 ± 5^{abA}	1.03	155 ± 11^{aB}	1.03	45 ± 3^{aA}	0.94	167 ± 7^{aB}	1.00
	0.010	68 ± 4^{cA}	1.33	173 ± 5^{bC}	1.14	84 ± 9^{bB}	1.75	623 ± 51^{cD}	3.73
	0.050	855 ± 23^{eA}	16.76	1123 ± 53^{dB}	7.43	846 ± 43^{cA}	17.63	1403 ± 45^{dC}	8.40

[1] Blank: see Table 2
[2] Abbreviation is the same as Table 1
[3] Mean ± standard deviation; separation within lines by Duncan's multiple range tests at 5% significant level. The horizontal axis is A, B and C; The vertical axis is a, b, c and d.
[4] Mutagenicity ratio = Induced revertants pre plate / Spontaneous revertants pre plate

strains. The revertant count of Blank of *S. typhimurium* TA98 (–S9) was 51 revertants/plate, while that of *S. typhimurium* TA100 was 151 revertants/plate. As Ames *et al*. (1975) indicated, if the His+ revertants/plate induced by the specimen is higher than the spontaneous revertants by over two times, or is dose dependent, it means it has mutagenicity. The revertant count of Blank of *S. typhimurium* TA98 (+S9) was 48 revertants/plate, while that of *S. typhimurium* was 167 revertants/plate. At test concentrations of 0.005 and 0.010 mg/plate, The *S. typhimurium* TA98 –S9 and +S9 revertant counts of methanol extracts of PBO, 10% SDRACP, and 40% SDRACP, were 52–75 and 45–84 revertants/plate, respectively, and the Mutagenicity ratios were 1.02–1.53 and 0.94–1.76. The *S. typhimurium* TA100 (–S9) revertant counts of methanol extracts at test concentrations of 0.005 and 0.010 mg/plate were 153–155 and 173–188 revertants/plate, respectively, while the Mutagenicity ratio was 1.01–1.03 and 1.14–1.24. The *S. typhimurium* TA100 (+S9) revertant counts of

Table 4. Comparison of GC–MS results among each acetone extracts separated from various SDRACP with peanut oil fume

Sort	Compound	PBO[1)]	10% SDRACP	40% SDRACP
Alkenals	(E,Z)–2,4–decadienal	11.37[2)]	–[3)]	–
	trans,trans–2,4–decadienal (t–t–2,4–DDE)	56.52	60.47	60.46
	trans,trans–2,4–undecadienal		–	0.27
Ester	Bis (O,O–diethyl phosphorodithioato–S,S')–	1.18	–	–
	Diisobutyl phthalate	–	1.84	–
	methyl palmitate	5.59	4.48	6.42
	Dibutyl Phthalate	2.14	3.24	2.31
	13–Octadecenoic acid methyl ester	6.77	6.89	5.25
	2–Propenoic acid, 2–(diethoxyphosphinyl)–3–[4–(dimethylamino) phenyl]–, ethyl ester	–	–	3.27
	Bis(2–ethylhexyl) Phthalate	1.63	0.92	1.62
Alkane	Decane	1.49	1.57	2.28
	Cyclooctane	–	1.24	–
	Undecane	–	1.32	–
	2–methyl undecane	0.41	–	–
	Dodecane	1.27	1.11	1.26
	Tridecane	–	1.51	–
	Tetradecane	1.25	–	–
	Cyclododecane	0.22	–	–
	Hexadecane	0.84	0.78	–
	Heptacosane	–	–	0.81
Aldehyde	Nonanal	–	4.78	3.42
	Decanal	0.29	–	0.33
Amine	Hexadecanamide	–	3.51	2.85
Alcohol	Cedrol	0.81	0.59	0.84
	1–Heptadecanol	1.27	1.32	–
	Parasiticol	1.12	1.22	1.05
Acid	Palmitic acid	–	–	1.89
	3–(4–N,N–Dimethylaminophenyl) propenoic acid	2.40	–	–
Ketones	7,9–Di–tert–butyl–1–oxaspiro(4,5)deca–6,9–diene–2,8–dione	1.59	1.99	2.52
Alkene	Cyclodecene	–	–	0.48
	1–Octadecene	0.17	–	–
	(E)–5–Octadecene	–	–	0.57
	Squalene	0.31	–	0.30
Phenol	2,6–Di–tert–butyl–4–methylphenol	0.97	1.22	0.96
Polycyclic aromatic hydrocarbons	Naphthalene	0.39	–	0.84

[1)] Abbreviation is the same as Table 1
[2)] Relative content
[3)] –: undetected

methanol extracts at test concentrations of 0.005 mg/plate were 167–174 revertants/plate, respectively, while the Mutagenicity ratio was 1.00–1.04. The above results show that the Mutagenicity ratio of *S. typhimurium* of methanol extracts at concentrations of 0.005 and/or 0.010 mg/plate, with or without S9, was lower than 2, representing no mutagenicity.

However, the revertant counts of *S. typhimurium* TA98 (–S9) and TA98 (+S9) of methanol extracts of PBO, 10% SDRACP, and 40% SDRACP at test concentration of 0.050 mg/plate were 790–860 and 812–889 revertants/plate, while the Mutagenicity ratios were 15.49–16.87 and 16.92–18.51, respectively. When the concentration was 0.050 mg/plate, the revertant count of *S. typhimurium* TA100 (–S9) was 1123–1279 revertants/plate, and the Mutagenicity ratio was 7.43–8.47. When S9 of methanol extracts of PBO, 10% SDRACP, and 40% SDRACP at test concentration of 0.010 and 0.050 mg/plate was added, the revertant count was 501–1435 revertants/plate, and the Mutagenicity ratio was 3.00–8.59. The Mutagenicity ratios of *S. typhimurium* TA98 (±S9) and TA100 (±S9) of methanol extracts at concentrations of 0.050 and 0.010–0.050 mg/plate were higher than two times, meaning the methanol extracts had very high mutagenicity, and the mutagenicity for *S. typhimurium* TA100 is higher than that of TA98, as well as there is significant difference.

Methanol extracts compounds analysis

The edible oil fume has mutagenicity because the polycyclic aromatic compounds, meaning aldehydes and ketones in the oil fume, may have genotoxicity (Chiang *et al*., 1997; Wu and Yen, 2000; Tung, 2003). The *S. typhimurium* TA98 (±S9) and TA100 (±S9) at concentration 0.050 and 0.010–0.050 mg/plate had mutagenicity for (Table 3). The n–hexane soluble fraction was obtained by dissolving the oil fume methanol extracts with n–hexane, and diluted 1000 times with n–hexane. The GC–MS analysis results are shown in Table 4.

The main compounds of PBO, 10% SDRACP, and 40% SDRACP by methanol extracts dissolving from peanut oil fume included Alkenals, Ester, Alkane, Aldehyde, Amine, Alcohol, Acid, Ketones, Alkene, Phenol, and Polycyclic aromatic hydrocarbons, and there were 60.47–67.89, 17.31–18.87, 4.35–7.53, 0.29–4.78, 0.00–3.51, 1.89–3.20, 0.00–2.40, 1.59–2.52, 0.00–1.35, 0.96–1.22, and 0.00–0.84% of relative content, respectively. The trans,trans–2,4–decadienal (t–t–2,4–DDE) of PBO, 10% SDRACP, and 40% SDRACP had the maximum relative content, which was 56.52–60.47%. This result matched the findings of Wu (1997), Wu (2004), Lin *et al*. (2018) and which indicate that t–t–2,4–DDE has the highest content of peanut oil fume (51.6%), the findings of Wu (1997) shows that t–t–2,4–DDE has mutagenicity when the concentration is 0.010 mg/plate, and the results of Lin *et al*. (2018) indicate that the t–t–2,4–DDE is the main mutagenic compounds of peanut oil fume, and may be one of the causes of human pulmonary adenocarcinoma. The findings of Tung (2003) indicates that the main alkenal t–t–2,4–DDE of edible oil fume can induce the apoptosis of human pulmonary adenocarcinoma cell strain. Wu (2004) indicates that 60% of lung cancer patients in Taiwan are pulmonary adenocarcinoma patients, and that women and cooks are more likely to get pulmonary adenocarcinoma. Therefore, t–t–2,4–DDE is the main mutagenic constituent of peanut oil fume.

CONCLUSION

The different proportions of SDRACP were made from SDRAC with the wood pulp and the value–added material of absorbability for the oil fume derived from the adsorbed oil by high temperature heating in food industry was investigated. The smoke point of peanut oil was 105±1˚C. The peanut oil fume absorption saturation of PBO, 10% SDRACP, and 40% SDRACP at the smoke point was 0.0442–0.0568 g/cm^2. This suggests the oil fume absorption of SDRACPs increases with the proportions of SDRACs. The methanol extraction yield was 0.41–1.11%. From the cytotoxicity results, methanol extracts at test concentrations higher than 0.100 mg/plate had cytotoxic reaction with *S. typhimurium* TA98 (±S9) and TA100 (±S9). For the mutagenicity results, the Mutagenicity ratios of *S. typhimurium* TA98 (±S9) and TA100 (±S9) of methanol extracts at a test concentration of 0.050 and 0.010 mg/plate were higher than two times, meaning methanol extracts had very high mutagenicity. The GC–MS analysis showed that trans–trans–2,4–decadienal (t–t–2,4–DDE) was the main mutagenic compounds of peanut oil fume.

AUTHOR CONTRIBUTION

Han Chien LIN designed this study, analyzed the data and the statistical analysis and wrote the paper. Wen–Ju Lee performed the experiments and participated in the design of the study. Noboru Fujimoto supervised the work and provided resources. The authors assisted in editing of the manuscript and approved the final version.

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