DEVELOPMENT OF DEFLECTOR FLAT SPRAY NOZZLE WITH MIXED OF WATER AND ORGANIC CITRIC ACID FOR EMISSIONS TRAP AND COOLING IN THE KITCHEN HOOD VENTILATION SYSTEM

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ABSTRACT

The growth of food industry is rapidly-evolving due to the increase of human population, which results in changes to the cooking technology development. This condition leads to increased pollution rate, especially air and water pollution. Recently, several technologies and research are developed to improve the commercial kitchen industry, especially in hotels and restaurants. The function of kitchen hood is to remove gas, odour, heat and steam during cooking process. The main purpose of this study is to introduce mist spray (atomization) to replace the water spray system in the existing kitchen hood. In addition, this study compared the existing (conventional) nozzles in the market such as KSJB model (water spray) and AL75 model (mist spray). Then, this study compared two nozzle designs of deflector nozzles that is ND2.5 A1.0 and ND2.5 B1.0. The difference between these two nozzles is the swirl angle. The swirl angles for ND2.5 A1.0 and ND2.5 B1.0 are 10^{o} and 15^{o} respectively. The use of the new nozzles is to reduce water consumption in the kitchen hood ventilation system. The other function is to introduce organic citric acid as an agent to absorb gas emitted during cooking, besides looking at the effect of nozzle design in limiting gas emission and reducing kitchen hood temperature during cooking. Several methods were used in this study, such as the development of a small size kitchen hood with one nozzle using water sensitive paper (WSP) to spray droplets with fluid pressure from one to six bar, using a gas analyzer for gas reading and thermocouple for temperature reading in the kitchen hood system. The results obtained from the comparison between KSJB model and AL75 model showed that the mist spray nozzle (AL75) is better than the water spray (KSJB) model. On average, the difference in gas emission percentage between AL75 and KSJB is 15.08 – 35.82 % while the difference in temperature is 2.98 – 11.35 %. Then, the comparison between the new nozzles shows that ND2.5 A1.0 is better than ND 2.5B1.0. On average, the difference in gas emission percentage between ND2.5 A1.0 and ND 2.5B1.0 is 2.65 – 24.32 % while the difference in temperature is 6.48 – 14.86 %. Lastly, comparison between AL75 and the new model which is ND2.5

A1.0 shows that ND2.5 A1.0 has better performance than AL75. On average, the difference in gas emission percentage between these two models is 13.12 – 33 % while the difference in temperature is 11.84 – 20.22 %. However, the AL75 nozzle can reduce water consumption by 60 – 80 % as compared to KSJB, depending on air pressure. The results show that the atomization nozzles (AL75, ND2.5 A1.0 and ND2.5 B1.0) have better effect than the water spray (KSJB) nozzle. The factors that improves kitchen hood performance are high spray angle, large droplet size and the usage of organic citric acid. In addition, mist spray can reduce water consumption and water pollution. In fact, the use of organic citric acid can reduce air pollution in the cooking process. For future studies, it is suggested to use an actual kitchen hood size for testing and the quantity for each nozzle type is increased in the kitchen hood system.

ABSTRAK

Perkembangan industri makanan mengalami transformasi dengan pesat berpunca daripada pertambahan populasi manusia, lalu membawa kepada perubahan dalam teknologi masakan. Keadaan ini menyebabkan peningkatan kadar pencemaran terutamanya pencemaran udara dan air. Baru-baru ini, terdapat pelbagai teknologi dan kajian dibangunkan untuk menambah baik industri dapur masakan komersial terutamanya di hotel dan restoran. Fungsi hud dapur adalah untuk menyingkirkan gas, bau, haba dan wap semasa proses memasak. Tujuan utama kajian ini adalah untuk memperkenalkan semburan kabus (pengabusan) bagi menggantikan system semburan air yang terdapat di dalam hud dapur yang sedia ada. Selain itu, kajian ini membandingkan muncung sedia ada (konvensional) yang terdapat dalam pasaran seperti model KSJB (semburan air) dengan model AL75 (semburan kabus). Kemudian, muncung dengan reka bentuk yang baharu (semburan kabus) iaitu model ND2.5 A1.0 dibandingkan dengan model ND2.5 B1.0. Kedua-dua muncung memiliki sudut pusaran yang berlainan. Sudut pusaran ND2.5 A1.0 dan ND2.5 B1.0 masing-masing adalah sebanyak 10^{o} dan 15^{o}. Penggunaan muncung yang baharu ini bertujuan untuk mengurangkan penggunaan air di dalam sistem pengalihudaraan hud dapur. Tujuan lain adalah untuk memperkenalkan bahan organik asid sitrik sebagai agen yang menyerap gas yang dibebaskan semasa memasak, selain meneliti kesan reka bentuk muncung dalam mengehadkan pelepasan gas dan mengurangkan suhu hud dapur semasa memasak. Terdapat beberapa kaedah yang digunakan dalam kajian ini, seperti mencipta sebuah hud dapur bersaiz kecil dengan satu muncung, dengan menggunakan water sensitive paper (WSP) bagi menyembur titisan kabus dengan tekanan bendalir sebanyak satu hingga enam bar. Tekanan di dalam sistem hud dapur ditentukan dengan menggunakan penganalisis gas bagi mendapatkan bacaan gas dan bacaan suhu diperoleh melalui pengganding suhu. Keputusan yang diperoleh daripada perbandingan antara model KSJB dengan model AL75 menunjukkan muncung semburan kabus (AL75) lebih baik daripada muncung semburan air (KSJB). Secara purata, perbezaan peratus pelepasan gas antara AL75 dan KSJB adalah sebanyak 15.08

– 35.82 % manakala perbezaan suhu adalah sebanyak 2.98 – 11.35 %. Kemudian, perbandingan antara muncung baharu menunjukkan prestasi ND2.5 A1.0 adalah lebih baik berbanding dengan ND 2.5B1.0. Secara purata, perbezaan peratus pelepasan gas antara ND2.5 A1.0 dan ND 2.5B1.0 adalah sebanyak 2.65 – 24.32 % manakala perbezaan suhu adalah sebanyak 6.48 – 14.86%. Akhir sekali, perbandingan antara AL75 dan model baharu iaitu ND2.5 A1.0 menunjukkan ND2.5 A1.0 mempunyai prestasi yang lebih baik daripada AL75. Secara purata, perbezaan peratus pelepasan gas antara kedua-dua model ini adalah sebanyak 13.12 – 33 % manakala perbezaan suhu adalah sebanyak 11.84 – 20.22 %. Walau bagaimanapun, muncung AL75 dapat mengurangkan pengunaan air sebanyak 60 – 80 % berbanding dengan muncung KSJB, bergantung pada tekanan udara. Keputusan menunjukkan muncung semburan kabus (AL75, ND2.5 A1.0 dan ND2.5 B1.0) memberi kesan yang lebih baik berbanding dengan muncung semburan air (KSJB). Faktor-faktor yang meningkatkan prestasi hud dapur ialah sudut semburan yang besar, saiz titisan semburan yang besar dan penggunaan bahan organik asid sitrik. Selain itu, semburan kabus juga dapat mengurangkan penggunaan air dan pencemaran air. Malah, penggunaan bahan organik asid sitrik dapat mengurangkan pencemaran udara yang terhasil semasa proses memasak. Cadangan bagi kajian akan datang adalah dengan menggunakan saiz hud dapur yang sebenar untuk membuat penilaian dan menambah bilangan setiap jenis muncung di dalam sistem hud dapur.

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LIST OF SYMBOLS AND ABBREVIATIONS

A	-	The spot area (μm^2)
AEA	-	American Economic Association
		Air-Conditioning Engineers
A_o	-	area of orifice
ASHRAE	-	American Society for Heating, Refrigerating and
$C_6H_8O_7$	-	Citric Acid
Cd	-	Discharge coefficient value
CKV	-	Commercial kitchen ventilation
CO	-	Carbon monoxide
CO_2	-	Carbon dioxide
cP	-	Centipoise
d	-	Droplet diameter
d_o	-	orifice diameter
DSLR	-	Digital Single Lens Reflex Camera
DWR	-	Department of Water Resources
FN	-	Flow Number
G	-	gas mass flow flux in kg/cm^2 hr
GLR	-	Gas / liquid mass ratio
H_2O	-	water .
KHV	-	Kitchen hood ventilation
L10	-	Lime Juice 10% + water 90%

L30	-	Lime Juice 30% + water 70%
LPG	-	liquid petroleum gas
MET	-	Malaysian Meteorological Department
ND	-	New design
NOx	-	Nitrogen oxide
P	-	Poise
Pa.s	-	Pascal seconds
PAI	-	People Action International
PCC	-	Phantom Camera Control
PM	-	Particulate matter
PVB	-	Portable Ventilator Blower
Q_A	-	Air Flow rate
Q_L	-	Liquid Flow rate
R1 or Rs	-	radius of swirl chamber
R2 or Rp	-	radius of inlet central port,
Re	-	Reynolds number
S	-	Swirl number
SG	-	specific gravity
SMD or D_{32}	-	Sauter mean diameter
SO_2	-	Sulphur dioxide
$\tan \gamma$	-	The swirl-generating vane tip angle.
TCA	-	tricarboxylic acid
VO	-	vegetable oil

VOC	-	Volatile organic compound
We	-	Weber number
WSP	-	Water sensitive paper –
(% v/v)	-	Volume percent
(l_o	-	outlet of port length
(m),	-	molar mass
(pH),	-	potential of hydrogen
(X),	-	mole fraction
d_o	-	Nozzle orifice diameter
u^2	-	Relative velocity,
ρ_a	-	Air density
ρ_{air}	-	Air density,
ρ_f	-	Liquid density
σ_{liquid}	-	The liquid surface tension.
ΔP	-	Differential liquid pressure
µm	-	microns meter
λ	=	$[\rho'_G \ \rho'_L]^{1/2}$
μ,	-	viscosity
μ'_L	-	Ratio of liquid viscosity to water viscosity at standard conditions $(\mu_{std(water),T=20^oC} = 1.002\ Cp)$
ρ	-	density
ρ'_G		Ratio of gas density to air density at standard conditions $(\rho_{std(air),T=20^oC} = 1.204\ {}^{kg}/_{m^3})$
σ.	-	surface tension
ψ	=	$(\sigma')^{-1}(\mu'_L)^{1/3}(\rho'_L)^{-2/3}$

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