UTILIZATION OF YEAST METABOLITES FOR BIOATTRACTION OF COCKROACH

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To my beloved family,

thank you for being there for me

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ABSTRACT

Cockroaches are among the most persistent pests that thrive in protected locations all over the world. Cockroach control using insecticides and other chemicals are not desirable because they are toxic to organisms and the environment. Pests can develop resistance to the chemicals, and chemical raw materials are from unsustainable source. This study was aimed to identify the novel potential of locally isolated yeasts, namely *Pichia kudriavzevii* M12 and *Candida ethanolica* M2 in cockroach attraction. The yeasts were fermented in potato dextrose broth (PDB) up to a week and tested for bioattraction of cockroaches at six locations at the student residential halls at Universiti Teknologi Malaysia (Johor, Malaysia). Either the 1-day or 4-day fermented broth from the yeasts were placed as the baits on sticky trap overnight in order to attract cockroaches. Freeze drying on the fermented broth was carried out and the resultant powder was sprinkled on the cockroach trap and tested for cockroach attraction. PDB was used as control. The 4-day fermented PDB of *P. kudriavzevii* M12 was found to be the better cockroach attractant, which trapped the highest number of both nymphs and adult cockroaches (an average of 48 cockroaches per catch). Ssuccessive attraction was done consecutively at the same location after two weeks, which resulted in a decrease of almost 80% of the cockroach population at the studied location. The metabolites in the 4-day fermented PDB of *P. kudriavzevii* M12 were profiled by liquid chromatography-mass spectrometry (LC-MS/MS), thus revealing the presence of secondary metabolites from the yeast strain for cockroach attraction. A total of 44 exometabolites with diverse properties and structures were identified and many were intermediates and products of the central metabolic pathway such as lipids, carboxylic acids and esters. In conclusion, *P. kudriavzevii* M12 showed a great potential as an eco-friendly cockroach attractant and the attraction could be as a result of the metabolites produced.

ABSTRAK

Lipas adalah antara perosak yang paling sering ditemui di pelbagai lokasi yang dilindungi di seluruh dunia. Kawalan terhadap lipas menggunakan racun serangga dan bahan kimia lain tidaklah diterima disebabkan oleh ketoksikan kepada organisma dan persekitaran. Perosak boleh membangunkan rintangan kepada bahan kimia, dan bahan-bahan mentah kimia adalah dari sumber yang tidak mapan. Kajian ini bertujuan untuk mengenal pasti potensi baru yis tempatan terpencil, iaitu *Pichia kudriavzevii* M12 dan *Candida ethanolica* M2 sebagai tarikan lipas. Yis telah ditapai dalam *potato dextrose broth* (PDB) sehingga seminggu dan diuji untuk tarikan lipas di enam lokasi di kediaman pelajar di Universiti Teknologi Malaysia (Johor, Malaysia). Sampel yang telah ditapai selama 1 hari dan 4 hari diletakkan sebagai umpan perangkap yang lekit untuk menarik lipas selama semalaman. Kering beku sampel yang ditapai telah dijalankan dan serbuk yang terhasil dipercikkan pada perangkap lipas dan diuji untuk tarikan lipas. Eksperimen kawalan dijalankan menggunakan PDB sahaja. Sampel yang ditapai selama 4 hari oleh *P. kudriavzevii* M12 didapati menjadi umpan lipas yang lebih baik, yang berjaya memerangkap bilangan tertinggi anak dan lipas dewasa (purata 48 lipas setiap tangkapan). Tarikan dilakukan berturutan di lokasi yang sama selepas dua minggu, yang mengakibatkan pengurangan populasi lipas sebanyak hampir 80% di lokasi yang dikaji. Metabolit dalam sampel PDB yang ditapai pada hari ke-4 oleh *P. kudriavzevii* M12 telah dikajikan menggunakan kromatografi cecair-spektrometri jisim (LC-MS/MS) mendedahkan bahawa terdapatnya metabolit sekunder dari yis. Sebanyak 44 metabolit dengan ciri-ciri dan struktur yang pelbagai telah dikenalpasti dan sebahagiannya adalah perantara dan produk laluan metabolik pusat seperti lemak, asid karbosilik dan ester. Kesimpulannya, *P. kudriavzevii* M12 menunjukkan potensi yang besar sebagai umpan lipas yang mesra alam dan tarikan adalah disebabkan oleh metabolit yang dihasilkan.

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LIST OF SYMBOLS/ABBREVIATIONS/NOTATIONS/TERMINOLOGY

Bla g 1	-	Cockroach allergen
Bla g 2	-	Cockroach allergen
bp	-	Boiling point
^{o}C	-	Degrees Celsius
DNA	-	Deoxyribonucleic acid
ESI	-	Electron Spray Ionization
g	-	gram
GC	-	Gas chromatography
HPLC	-	High performance liquid chromatography
LC	-	Liquid chromatography
LC-MS/MS	-	Liquid chromatography tandem mass spectrometry
MALDI	-	Matrix assisted laser desorption/ionization
mb	-	Milli bar
mmHg	-	Millimeters of mercury
MS	-	Mass spectroscopy
nm	-	nanometer
OD	-	Optical density
PDA	-	Potato dextrose agar
PDB	-	Potato dextrose broth
rpm	-	Revolutions per minute

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Cockroaches (order: *Blatteria*) are among the most persistent pests that thrive in protected locations all over the world. American, brown-banded, German and Oriental cockroaches are the four most common species in human habitats (Hahn and Ascerno, 2005). They can be found in boiler rooms, heated steam tunnels, floor drains, water heaters, bath tubs (Eggleston and Arruda, 2001), kitchen sink, wall cracks, underneath or inside cupboards, behind drawers, around pipes or conduits, behind window or door frames, in radio and TV cabinets (Koehler *et al.*, 2007).

Cockroaches are objectionable because they compete with humans for food, carry allergens in saliva, fecal material, secretions, cast skins, debris and dead bodies that can lead to asthma in humans (Eggleston and Arruda, 2001), harbor pathogenic bacteria, contaminate paper and fabrics, and impart repulsive stains and odours (Koehler *et al.*, 2007) .

The life cycle of cockroach consists of egg, nymph and adult and they can live for one year. Nymphs are more than adults in natural populations (Hahn and Ascerno, 2005). Cockroaches are nocturnal and omnivorous and will eat anything though they can stay for about one month without food and for about two weeks without water. Cockroach population in an enclosure is governed by presence of food and water, height of location (for some species), humidity, temperature darkness (Eggleston and Arruda, 2001) and history of control measures (Wang and Bennett, 2006).

Trapping, mating distruptions, attracticides are used in cockroach control. Organophosphates, carbamates, pyrethrins, chlorinated hydrocarbons and inorganics are some of the pesticides used to control cockroaches (Eggleston and Arruda, 2001). Traps are relatively more effective in controlling cockroach (Rust *et al.*, 1999). Attractiveness of methylcyclohexyl n-alkanoates to the German cockroach was reported by Iida and co-workers (Iida *et al.*, 1981). Many chemical attractants used in commercial cockroach traps are injurious to humans and the environment (Quesada *et al.*, 2004). Pest resistance, toxicity and non-sustainable raw materials of pesticides are some of the factors behind the trend to replace chemical feedstock, processes and end products with bio-based alternatives.

Cockroaches emit pheromones for communication and other activities. Three semiochemicals from stale beer and peanut butter are capable of being used as cockroach bioattractants were identified by Karimifar and co-workers (Karimifar *et al.*, 2011). Foods such as bread, peanut butter, molasses and beer can act as cockroach attractants. Food baits are not used in commercial pest control strategies as they often turn out to be breeding grounds for pests (Cox and Collins, 2002). Many insects respond to chemicals released by same species or chemicals released by other organisms. Many plants release volatile chemicals that are able to affect other organisms such as insects. Semiochemicals are pheromones and allelochemicals, many of which are responsible for insect behaviors such as feeding and reproduction. They are mostly volatile metabolites that are involved in signaling and other functions (Maffei, 2010).

Metabolites are involved in metabolism either as intermediates or as the final products. Metabolism can be divided into anabolism in which simple molecules are used to build large, complex molecules and catabolism in which complex, large molecules are broken into simple molecules. Most of the time, each metabolite can serve more than one purpose (Kooijman and Segel, 2005). Most metabolites are within cells where they are utilized by enzymes in various biochemical reactions. Some of the metabolites have control functions. Metabolites include lysine, riboflavin (Damain, 1980), ethanol, acetic acid (Styger *et al.*, 2011). Two subgroups of metabolites are primary and secondary metabolites. Primary metabolites have physiological functions (Gika *et al*, 2012). Secondary metabolites serve ecological functions (Demain, 1998). Primary pathways normally yield few products but are present in many organisms. Secondary metabolic pathways yield many products but are present in few organisms. Antibiotics make up most of the 50 most important secondary metabolites (Demain, 1999).

Volatile metabolites are intermediates and final products of metabolism. A major feature of volatile metabolites is the ease of evaporation at normal temperature and pressure. They act over a wide range of distances, concentration and environment (Humphris *et al*., 2002). Yeasts produce volatile metabolites which can be grouped into alcohols, acids, esters, ketones and phenols. Such volatiles include ethanol, 3-methyl-1-butanol, 3- hydroxyl-2-butanone, ethyl propanoate, 2-phenyl-ethanol (Nout and Bartelt, 1998). Volatile metabolites are useful to both the organism producing them and other organisms. Volatiles are useful as flavors, fragrances (Berger, 2009), inhibitors (Ting *et al*., 2010), and attractants (Rowan, 2011), as well as for communication (Maffei, 2010), identification and profiling (Frisvad *et al*., 2007), and detection of contaminants (Berge *et al*., 2011). Volatile metabolites are produced by plants, animals, microorganisms and through chemical synthesis. Yields from plants and animals are low compared to microbial sources (Vandamme, 2003). Plant cell cultures are not economically viable for producing volatile metabolites (Verpoorte *et al*., 2002). Chemical (synthetic) volatile metabolites are relatively cheap with large market share but disadvantaged by perceived environmental toxicity and possible formation of recemic mixtures (Longo and Sanroman, 2006). Major advantages of microbial based production of volatile metabolites include low energy input, reduced emission of pollutants, easy purification and renewable raw materials (Chelmer *et al*., 2006). Some volatile metabolites are produced through microbial fermentation of various substrates. Microbial volatile production depends on medium, species (Borjesson et al., 1992), temperature, pH, initial aeration (Reddy and Reddy, 2011), culture age and volatiles from other microorganisms (Tirranen and Gitelson, 2006).

Yeasts are the most suitable source for microbial volatile production as they tolerate high sugar concentration, anaerobic growth, high salt concentration, resistance to inhibitors in the biomass (Nevoigt, 2008). An alcoholic fermentation takes place in the absence of oxygen and presence of yeasts, nutrient medium, suitable pH and temperature. Alcohols, vitamins, hormones, antibiotics, enzymes, acids are made through fermentation. Yeast utilization of glucose can be through the fermentation of glucose, oxidation of glucose or oxidation of ethanol. *Saccharomyces cerevisiae* can completely ferment glucose, fructose, galactose, sucrose and maltose (Yoon *et al.*, 2003). Volatile metabolites are produced during bacterial and yeast fermentations but in an experiment, only volatile metabolites from yeast fermentation were able to attract insects (Nout and Bartelt, 1998).

The *Saccharomycetaceae* family has about 20 genera, which include *Saccharomyces, Candida* and *Pichia*. Members of the family reproduce by budding and live in environments rich in carbohydrates. *Saccharomyces cerevisiae* is the most important yeast as a model eukaryotic organism. *Saccharomyces cerevisiae* is used in baking, brewing and wine making. *Saccharomyces cerevisiae* and closely related yeasts dominate alcoholic fermentations as they are tolerant of high alcohol content and they also use the produced ethanol as feedstock (Piskur *et al.*, 2006).

Candida ethanolica was first isolated from industrial fodder yeast and can grow on ethanol as the only carbon source. *C. ethanolica* is one of the yeasts involved in *shubat* (a fermented camel milk) production (Shori, 2012), Ghanaian heaped cocoa bean fermentation (Daniel *et al.*, 2009), *mescal* (Mexican distilled beverage) (Valdez, 2011), sour cassava starch fermentation (Lacerda *et al.*, 2005).

Pichia kudriavzevii is synonymous with *Issatchenkia orientalis* based on molecular, biochemical and phenotypic characterization (Bhadra *et al.*, 2007). *Pichia kudriavzevii* was shown to degrade phytate in '*togwa*', a cereal food in Tanzania (Hellstrom *et al.*, 2012), produce ethanol from alkali-treated rice straw (Oberoi *et al.*, 2012), ferment cotton stalks in a combined saccharification and fermentation process for ethanol production (Kaur *et al.*, 2012), part of *fen-daqu*, starter culture for Chinese liquor production (Zheng *et al.*, 2012), among the yeasts involved in '*tchapalo*', a local beer in Cote d' Ivoire (N'guessan *et al.*, 2011) and among the yeasts involved in Ghanaian heap cocoa bean fermentation (Daniel *et al.*, 2009).

Media composition is important in yeast fermentation performance (Hahn-Hagerdal *et al.*, 2005). Agar plates and nutrient broth are used in most yeast fermentations. Among the common media for yeast fermentation are wort (Lodolo *et* *al.*, 2008), molasses (Alegre *et al.*, 2003) and potato dextrose broth (Kalyani *et al.*, 2000). Yeast stock cultures are normally kept at 4^{o}C on potato dextrose agar (Lakshmanan and Radha, 2012). Most yeast utilize hexose sugars (monosaccharides and disaccharides). The media used can improve yield, increase biomass formation and decrease fermentation period (Chunkeng *et al.*, 2011). The ecology and profile of microorganisms during fermentation could be affected by the media used (Hsieh *et al.*, 2012). Potato dextrose broth is commonly used for the cultivation of yeasts and molds. Its low pH discourages bacterial growth (Condolab, 2012).

Chromatography is used to separate complex mixtures but it cannot readily identify the constituents of separated unknown mixtures. It is always desirable to couple separation processes to identification steps. Liquid chromatography (LC) and gas chromatography (GC) are two of the leading chromatographic methods. LC is favoured over GC for samples susceptible to degradation as LC does not involve derivation step. In order to identify, LC is normally coupled to mass spectrometry (MS) that is in tandem. Liquid chromatography – tandem mass spectrometry (LC-MS/MS) was found to have lower limit of quantification, less costly to run, reduced preparation time, does not involve derivation of sample, and reduced run time (Coles *et al.*, 2007). LC-MS/MS is best suited for the analysis of chemically and thermally unstable compounds (Johnson, 2005).

Downstream processing involves the recovery of the desired product from the fermentation broth. Removal of insolubles, product isolation, product purification and product polishing are the major groupings of the unit operations of fermentation products recovery. Low product concentration makes product recovery expensive (Schugerl, 2000).

Freeze drying (lyophilization) is a dehydration process in which solvent is removed through sublimation. It is used for the recovery of heat sensitive products such as volatile metabolites. Compared to air drying, the retention of volatile materials was more in the freeze dried sample (Krokida and Philippoules, 2006).

1.2 Statement of Problem

Cockroach control using insecticides and other chemicals are not desirable because they are toxic to organisms and the environment (Quesada *et al.*, 2004). Pests can develop resistance to the chemicals. In addition, chemicals are unsustainable as the raw materials of the chemicals are from petroleum. Hence, there is consumer demand for natural product based compounds.

On the other hand, foods as attractants favour all organisms thereby providing breeding grounds (Cox and Collins, 2002). Foods have limited range of effectiveness and are non-specific.

Biological based attractants from plants and animals are very low in yields (Vandamme, 2003). Extraction from plants is very difficult, depends on the season and some of the exotic plants have lost the ability to produce desired volatile metabolites (Dudareva and Pichersky, 2000).

Microorganisms produce volatile metabolites that can potentially act as insect attractants. Volatile metabolites from yeasts have been found to be better at attracting insects than volatile metabolites from bacteria (Nout and Bartelt, 1998).

Therefore, there is the need to test if volatile metabolites from yeast fermentation can attract cockroaches and the leading volatile metabolites responsible for the attraction. In this study, two locally isolated yeasts, namely *Candida ethanolica* M2 and *Pichia kudriavzevii* M12 were tested for their potential in bioattraction of domestic cockroaches and production of exometabolites.

1.3 Objectives of the Research

The specific objectives of this study were:

1. To determine the potential of yeast strains *C. ethanolica* M2 and *P. kudriavzevii* M12 in producing metabolites for bioattraction of domestic cockroaches
2. To compare the fresh and freeze-dried yeast culture supernatants in its efficiency in bioattraction of domestic cockroaches
3. To study the exometabolites of *P. kudriavzevii* M12

1.4 Scope of Research

This research work focused on the production of volatile metabolites from yeast strains *C. ethanolica* M2 and *P. kudriavzevii* M12 which were cultured in potato dextrose broth (PDB) up to a period of a week. The culture supernatant containing volatile metabolites were tested as bait of commercial trap for the attraction of domestic cockroaches at six different locations at the student residential halls in Universiti Teknologi Malaysia. Freeze-drying of the culture supernatant was attempted as a preservation technique and the efficiency of the freeze-dried metabolites in bioattraction of cockroach was determined. As the fermentation of *P. kudriavzevii* M12 was found to be significant, LC-MS/MS profiling was performed to determine the leading metabolites in the supernatant from the four-days fermentation broth.

1.5 Significance of Research

This research is significant as it has the potential to discover non-toxic, natural bait from yeasts which may replace the harmful chemical baits in domestic cockroach traps. In the future, the identified metabolites could be optimized for the production of cheap bait for domestic cockroach attraction.

REFERENCES

Abbas, K. A. (2010). The significance of glass transition temperature in processing of selected fried food products: A review. *Modern Applied Science*, 4(5), 3-21.

Abraham, B. G., and Berger, R. G. (1994). Higher fungi for generating aroma components through novel biotechnologies. *Journal of Agricultural and Food Chemistry* 42, 2344-2348.

Alegre, R. M., Rigo, M., and Joekes, I. (2003). Ethanol fermentation of a diluted molasses medium by *Saccharomyces cerevisiae* immobilized on chrysotile. *Brazilian Archives of Biology and Technology*, 46(4), 751-757.

Appling, D. R. (1991). Compartmentation of folate-mediated one-carbon metabolism in eukaryotes. *The FASEB Journal*, 5, 2645-2651.

Arranz, S., Chiva-Blanch, G., Valderas-Marinez, P., Medina-Remon, A., Lamuela-Raventos, R. M., and Estruch, R. (2012). Wine, beer, alcohol and polyphenols on cardiovascular disease and cancer. *Nutrient*, 4, 759-781.

Arruda, L. K., Vailes, L. D., Ferriani, V. P. L., Santos, A. B. R., Pomes, A., and Chapman, M. D. (2001). Cockroach allergen and asthma. *Journal of Allergy and Clinical Immunology*, 107, 419-428.

Bai, F. W., Anderson, W. A., and Moo-Young, M. (2008). Ethanol fermentation technologies from sugar and starch feedstocks. *Biotechnology Advances*, 26, 89-105.

Bajad, S. U., Lu, W., Kimball, E. H., Yuan, J., Peterson, C., and Rabinowitz, J. D.

(2006). Separation of quantification of water soluble cellular metabolites by hydrophilic interaction chromatography- tandem mass spectrometry. *Journal of Chromatography* A, 1125, 76-88.

Batra, S. W. T. (1985). Polyester-making bees and other innovative insect chemists. *Journal of Chemical Education*, 62(2), 121-124.

Baudot, A., and Marin, M. (1996). Dairy aroma compounds recovery by pervaporation. *Journal of Membrane Science*, 120, 207-220.

Berge, P., Ratel, J., Fournier, A., Jondreville, C., Feidt, C., Roudaut, B., Le Bizec, B., and Engel, E. (2011). Use of volatile compound metabolic signatures in poultry liver to back-trace dietary exposure to rapidly metabolized xenobiotics. *Environmental Science and Technology*, 45, 6584-6591.

Berger, R. G. (2009). Biotechnology of flavours – the next generation. *Biotechnology Letters*, 31,1651-1659.

Bhadra, B., Rao, R. S., Kumar, N. N., Chaturvedi, P., and Sarkar, P. K. (2007). *Pichia cecembensis sp*. nov. isolated from a papaya fruit (*Carica papaya* L., Caricaceae). *FEMS Yeast Research*, 7(4), 579-584.

Bhandari, B. R., and Howes, T. (1999). Implication of glass transition for the drying and stability of dried foods. *Journal of Food Eengineering*, 40, 71-79.

Bi, P. Y., Dong, H. R., and Guo, Q. Z. (2009). Separation and purification of Penicillin G from fermentation broth by solvent sublation. *Separation and Purification Technology*, 65, 228-231.

Bianchi, F., Careri, M., Mangia, A., Mattarozzi, M., Musci, M., Concina, I., and Gobbi, E. (2010). Characterisation of the volatile profile of orange juice contaminated with *Alicyclobacillus acidoterrestris*. *Food Chemistry*, 123, 653-658.

Billheimer, J. T., Avart, S., and Milani, B. (1983). Separation of steryl esters by reverse-phase liquid chromatography. *Journal of Lipid Research*, 24,1646-1651.

Boch, R., Shearer, D. A., and Stone, B. C. (1962). Identification of isoamyl acetate as an active component of the sting pheromone of the honey bee. *Nature*, 195, 1018-1020.

Bode, R., and Birnbaum, D. (1987). D-amino acid oxidase, aromatic L-amino amino-transferase, and aromatic lactate dehydrogenase from several yeast species: Comparison of enzyme activities and enzyme specificities. Ac*ta Biotechnology*, 7(3), 221-225.

Boldyrev, A. A., Stvolinsky, S. L., Fedorova, T. N., and Suslina, Z. A. (2010). Carnosine as a natural antioxidant and geroprotector: from molecular mechanisms to clinical trials. *Rejuvenation Research,* 3(2-3), 156-158.

Borjesson, T., Stollman, U., and Schnurer, J. (1990). Volatile metabolites and other indicators of *Penicillium aurantiogriseum* growth on different substrates. *Applied and Environmental Microbiology*, 56(12), 3705-3710.

Borjesson, T., Stollman, U., and Schnurer, J. (1992). Volatile metabolites produced by six fungal species compared with other indicators of fungal growth on cereal grains. *Applied and Environmental Microbiology*, 58(8), 2599-2605.

Botella, C., Diaz, A. B., Wang, R., Koutines, A., and Webb, C. (2009). Particulate bioprocessing: A novel process strategy for biorefineries. *Process Biochemistry*, 44, 546-555.

Breitling, R., Pitt, A. R., and Barrett, M. P. (2006). Precision mapping of the metabolome. *Trends in Biotechnology*, 24(12), 543-548.

Brindley, D. N., English, D., Pilquil, C., Buri, K. and Ling, Z. (2002). Lipid phosphate phosphatases regulate signal transduction through glycerolipids. *Biochimica et Biophysica Acta*, 1582, 33-44.

Bunch, A. W., and Harris, R. E. (1986). The manipulation of micro-organisms for the production of secondary metabolites. *Biotechnology and Genetic Engineering Review*, 4, 117-144.

Cao, L., Zhang, P., and Grant, D. F. (2009). An insect farnesyl phosphatase homologuous to the N-terminal domain of soluble epoxide hydrolase. *Biochemical and Biophysical Research Communications*, 380, 188-192.

Casaregola, S., Weiss, S., and Morel, G. (2011). New perspectives in hemiascomycetous yeast taxonomy. *C. R. Biologies*, 334, 590-598.

Cecchini, F., Manzano, M., Manddabi, Y., Perelman, E., and Marks, R. S. (2012). Chemiluminescent DNA optical fibre sensor for *Brettanomyces bruxellensis*. *Journal of Biotechnology*, 157, 25-30.

Chan, G. F., Gan, H. M., Ling, H. L., and Rashid, N. A. A. (2012). Genome sequence of *Pichia kudriavzevii* M12, a potential producer of bioethanol and phytase. *Eukaryotic Cell*, 11(10), 1300-1301.

Chemler, J. A., Yan, Y., and Koffas, M. A. G. (2006). Biosynthesis of isoprenoids, polyunsaturated fatty acids and flavonoids in *Saccharomyces cerevisiae*. *Microbial Cell Factories*, 5(20), 1-9.

Chen, H., Lee, Y., Wei, Y., and Juang, R. (2008). Purification of surfactin in pretreated ermentation broth by adsorptive removal of impurities. *Biochemical Engineering Journal*, 40, 452-459.

Christ (2012). Smart freeze drying. Retrieved December 11, 2012 from http://www.martinchrist.de/fileadmin/my_uploads/christ/ en/Christ_Theorie_Katalog_en_web.pdf

Christie, W. W., (2012). Phosphatidic acid, lysophosphatidic acid and related lipids: Structure occurence, biochemistry and analysis. Retrieved December 19, 2012 from http://www. lipidlibrary.aocs.org.

Chunkeng, H., Qing, Q., and Peipei, G. (2011). Medium optimization for improved ethanol production in very high gravity fermentation. *Chinese Journal of Chemical Engineering*, 19(6), 1017-1022.

Cocolin, L., Bisson, L. F., and Mills, D. A. (2000). Direct profiling of the yeast dynamics in wine fermentations. *FEMS Microbiology Letters*, 189, 81-87.

Coetzee, C., and du Toit, W. J. (2012). A comprehensive review on Sauvignon blanc aroma with a focus on certain positive volatile thiols. *Food Research International*, 45, 287-298.

Coles, R., Kushnir, M. M., Nelson, G. J., McMullin, G. A., and Urry, F. M. (2007). Simultaneous determination of codeine, morphine, hydrocodone, hydromorphone, oxycodone, and 6-acetylmorphine in urine, serum, plasma, whole blood, and meconium by LC-MS/MS. *Journal of Analytical Toxicology*, 31,1-14.

Condalab (2012). Potato dextrose broth. Retrieved December 9, 2012 from www.condalab.com/pdf/1261.pdf

Conner, W. E., Eisner, T., Vander Meer, R. K., Guerrero, A., and Meinwald, J. (1981). Precopulatory sexual interaction in an arctiid moth (*Utetheisa ornatrix*): Role of a pheromone derived from dietary alkaloids. *Behavioural Ecology and Sociobiology*, 9, 227-235.

Cottier, F. and Muhlschlegel, F.A. (2012). Communication in fungi. *International Journal of Microbiology*. doi:10.1155/2012/351832

Cox, P. D., and Collins, L. E. (2002). Factors affecting the behaviour of bettle pests in stored grain, with particular reference to the development of lures. *Journal of Stored Products Research*, 38, 95-115.

Cramer, S. M., and Holstein, M. A. (2011). Downstream bioprocessing: Recent advances and future promise. *Current Opinion in Chemical Engineering*, 1, 27-37.

Damain, A. L. (1980). Microbial production of primary metabolites. *Naturwissenschaften*, 67, 582-587.

Damain, A. L. (1998). Induction of microbial secondary metabolism. *International Microbiology*, 1, 259-264.

Damain, A. L. (1999). Pharmaceutically active secondary metabolites of microorganisms. *Applied Microbiology and Biotechnology*, 52, 455-463.

Daniel, H., Vrancken, G., Takrama, J. F., Camu, N., De Vos, P., and De Vuyst, L. (2009).Yeast diversity of Ghanaian cocoa bean heap fermentation. *FEMS Yeast Research*, 9, 774-783.

Dear, G. J., Fraser, I. J., Patel, D. K., Long, J., and Pleasance, S. (1998). Use of liquid chromatography-tandem mass spectrometry for the quantitative and qualitative analysis of antipsychotic agent and its metabolites in human plasma and urine. *Journal of Chromatography A*, 794, 27-36.

De Lucca, S. D., Taylor, D. J. M., O'Meara, T. J., Jones, A. S., and Tovey, E. R. (1999). Measurement and characterization of cockroach allergens detected during normal domestic acivity. *Journal of Allergy and Clinical Immunology*, 104(3), 672-680.

De Torres, C., Diaz-Maroto, M. C., Hermosin-Gutierrez, I., and Perez-Coello, M. S. (2010).Effect of freeze-drying and oven drying on volatiles and phenolics composition of grapeskin. *Analytica Chimica Acta*, 660, 177-182.

Dickson, R. C., New insights into sphingolipid metabolism and function in budding yeast.*Journal of Lipid Research*, 49, 909-921.

Dien, B. S., Cotta, M. A., and Jeffries, T. W. (2003). Bacteria engineered for fuel ethanol production: Current status. *Applied Microbiology and Biotechnology*, 63, 258-266.

Diez, J., Martinez, J. P., Mestres, J., Sasse, F., Frank, R., and Meyerhaus, A. (2012). Myxobacteria: natural pharmaceutical factories. *Microbial Cell Factories*, 11 (52), 1-3.

Dinglasan, M. J. A., Ye, Y., Edwards, E. A., and Mabury, S. A. (2004). Fluorotelomer alcohol biodegradation yields poly- and perflourinated acids. *Environmental Science and Technology*, 38, 2857-2864.

Dudareva, N., and Pichersky, E. (2000). Biochemical and molecular genetic aspects of floral scents. *Plant Physiology*, 122, 627-633.

Dudareva, N., and Pichersky, E. (2008). Metabolic engineering of plant volatiles. *Current Opinion in Biotechnology*, 19, 181-189.

Edris, A. E., and Malone, C. R. (2011). Formulation of banana aroma impact ester in water-based microemulsion nano-delivery system for flavoring applications using sucrose laurate surfactant. *Procedia Food Science*, 1, 1821-1827.

Eggleston, P. A., and Arruda, L. K. (2001). Ecology and elimination of cockroaches and allergens in the home. *Journal of Allergy and Clinical Immunology*, 107(3), S422-S429.

Ekesi, S., Maniania, N. K., and Lux, S. A. (2003). Effect of soil temperature and moisture on survival and infectivity of *Metarhizium anisopliae* to four tephritid fruit fly puparis. *Journal of Invertebrate Pathology*, 83, 157-167.

El-Sayed, A. M., Heppelthwaite, V. J., Manning, L. M., Gibb, A. R., and Suckling, D. M.(2005). Volatile constituents of fermented sugar baits and their attraction to Lepidopteran species. *Journal of Agricultural and Food Chemistry*, 53, 953-958.

Emelyanova, E. V. (2000). Relationship between magnesium and iron uptake by the yeast *Candida ethanolica*. *Process Biochemistry*, 36, 517-523.

Enomoto, H., Ishida, T., Hamagami, A., and Nishida, R. (2010). 3-Oxygenated α-ionone derivatives as potent male attractants for the solanaceous fruit fly, *bactrocera latifrons* (Diptera : Tephritidae), and sequestered metabolites in the rectal gland. *Applied Entomology and Zoology*, 45(4), 551-556.

Erten, H., and Tanguler, H. (2010). Influence of Williopsis saturnus yeasts in combination with *Saccharomyces cerevisiae* on wine fermentation. *Letters in Applied Microbiology*, 50, 474-479.

Figueiredo, A. C., Barroso, J. G., Pedro, L. G., and Scheffer, J. J. C. (2008). Factors affecting secondary metabolite production in plants: Volatile components and essential oils. *Flavour and Fragrance Journal*, 23(4), 213-226.

Fitzgerald, R. L., Riveria, J. D., and Herold, D. A. (1999). Broad spectrum drug identification directly from urine, using liquid chromatography – tandam mass spectrometry. *Clinical Chemistry*, 45(8), 1224-1234.

Fleet, G. H. (1990). Yeast in dairy products. *Journal of Applied Bacteriology*, 68, 199-211.

Flink, J., and Karel, M. (1970). Retention of organic volatiles in freeze-dried solutions of carbohydrates. *Journal of Agricultural and Food Chemistry,* 18(2), 295-297.

Florez, A. B., Belloch, C., Alvarez-Martin, P., Querol, A., and Mayo, B. (2010). *Candida cabralensis* sp. nov., a yeast species isolated from traditional Spanish blue-veined Cabrales cheese. *International Journal of Systematic and Evolutionary Microbiology*,60, 2671-2674.

Forster, J., Famili, I., Fu, P., Palsson, B., and Nielsen, J. (2003). Genome-scale reconstruction of the *Saccharomyces cerevisiae* metabolic network. *Genome Research*, 13(2), 244-253.

Frisvad, J. C., Larson, T. O., de Vries, R., Meijer, M., Houbraken, J., Cabanes, F. J., Ehrlich, K., and Samson, R. A. (2007). Secondary metabolite profiling, growth profiles and other tools for species recognition and important *Aspergillus* mycotoxins. *Studies in Mycology*, 59, 31-37.

Fukuda, K., Yamamoto, N., Kiyokawa, Y., Yanagiuchi, T., Wakai, Y., Kikamoto, K., Inoue,Y., and Kimura, A. (1998). Balance of activities of alcohol acetyltransferase and esterase in Saccharomyces cerevisiae is important for production of isoamyl acetate. *Applied and Environmental Microbiology*, 64(10), 4076-4078.

Fukuda, K., Yamamoto, N., Kiyokawa, Y., Yanagiuchi, T., Wakai, Y., Kikamoto, K., Inoue, Y., and Kimura, A. (2000). Purification and characterization of isoamyl acetate-hydrolyzing esterase encoded by the IAH1 gene of *Saccharomyces cerevisiae* from a recombinant *Escherichia coli*. *Applied Microbiology and Biotechnology*, 53, 596-600.

Gaid, M. M., Sircar, D., Muller, A., Beurle, T., Liu, B., Ernst, L., Hansch, R., and Beerhues,L. (2012). Cinnamate: CoA ligase initiates biosynthesis of a benzoate derived xanthone phytoalex in hypericum calycinum cell cultures. *Plant Physiology Preview*, doi:10.1104/pp.112.204180.

Garcia, C. V., Stevenson, R. J., Atkinson, R. G., Winz, R. A., and Quek, S. (2013). Changes in the bound aroma profiles of 'Hayward' and 'Hort16' kiwifruit (*Actinidia spp*.) during ripening and GC-olfactometry analysis. *Food Chemistry*, 137, 45-54.

Geiger, O., Lopez-Lara, I. M., and Sohlenkamp, C. (2012). Phosphatidylcholine biosynthesis and function in bacteria. *Biochemica et Biophysica Acta*, xxx-xxx

Gika, H. G., Theodoridis, G. A., Vrhovsek, U., and Mattivi, F. (2012). Quantitative profiling of polar primary metabolites using hydrophilic interaction ultrahigh performance liquid chromatography-tandem mass spectroscopy. *Journal of Chromatography A*, 1259, 121-127.

Gillooly, D. J., Morrow, I. C., Lindsay, M., Gould, R., Bryant, N. J., Gaullier, J., Parton, R.G., and Stenmark, H. (2000). Localization of phosphatidylinositol 3-phosphate in yeast and mammalian cells. *The EMBO Journal*, 19(17), 4577-4588.

Goffeau, A., Barrell, B. G., Bussey, H., Davis, R. W., Dujon, B., Feldmann, H., Galibert, F., Hoheisel, J. D., Jacq, C., Johnston, M., Louis, E. J., Mewes, H. W., Murakami, Y., Philippsen, P., Tettelin, H., and Oliver, S. G. (1996). Life with 6000 genes. *Science*, 274(5287), 546-567.

Gounaris, Y. (2010). Biotechnology for the production of essential oils, flavours and volatile ,isolates. A review. *Flavor and Fragrance Journal*, 25(5), 367-386.

Grebe, S. K. G., and Singh, R. J. (2011). LC-MS/MS in clinical laboratory – where to from here? *Clinical Biochemistry Review*, 32, 5-31.

Hahn, J. D., and Ascerno, M. E. (2005). Cockroaches. University of Minnesota

Extension. Retrieved December 29, 2012 from http://www1.extension.umn.edu/garden/insects/find/cockroaches/

Hahn-Hagerdal, B., Karhumaa, K., Larsson, C. U., Gorwa-Grauslund, M., Gorgens, J., and van Zyl, W. H. (2005). Role of cultivation media in the development of yeast strains for large scale industrial use. *Microbial Cell Factories*, 4(1), 31.

He, S., Jiang, L., Wu, B., Pan, Y., and Sun, C. (2009). Pallidol, a resveratrol dimer from the wine, is a selective singlet oxygen quencher. *Biochemical and Biophysical Research Communications*, 379, 283-287.

Healy, T.P., Copland, M.J.W., Cork, A., Przyborowska, A. and Halket, J.M. (2002). Landing responses of *Anopheles gambiae* elicited by oxocarboxylic acid. *Medical and Veterinary Entomology*. 16, 126-132.

Heimovitz-Friedman, A., Kan, C. C., Ehleiter, D., Persaud, R. S., McLoughlin, Z., Fuks, Z., and Kolenick, R. N. (1994). Ionizing radiation acts on cellular membranes to generate ceramide and initiate apoptosis. *Journal of Experimental Medicine*, 180, 525-535.

Hellstrom, A. M., Almgren, A., Carlsson, N., Svanberg, U., and Andlid, T. A. (2012). Degradation of phytate by *Pichia kudriavzevii* TY13 and Hanseniaspora *guilliermondii* TY14 in Tanzania togwa. *International Journal of Food Microbiology*, 153(1-2), 73-77.

Heringdorf, D. M., and Jacobs, K. H. (2007). Lysophospholipid receptors: Signalling, pharmacology and regulation by lysophospholipid metabolism. *Biochemica et Biophysica Acta*, 1768, 923-940.

Heuskin, S., Verheggen, F. J., Haubruge, E., Wathelet, J., and Lognay, G. (2011). The use of semiochemicals slow-release devices in integrated pest management strategies. *Biotechnology Agronomy Society and Environment*, 15(3), 459-470.

Hsieh, H., Wang, S., Chen, T., Huang, Y., and Chen, M. (2012). Effect of cow's and goat's milk as fermentation media on the microbial ecology of sugary *kefir* grains. *International Journal of Food Microbiology*, 157, 73-81.

Humphris, S. N., Bruce, A., Buultjens, E., and Wheatley, R. E. (2002). The effects of volatile microbial secondary metabolites on protein synthesis in *Serpula lacrymans*. *FEMS Microbiology Letters*, 210, 215-219.

Iacumin, L., Manzano, M., Cecchini, F., Orlic, S., Zironi, R., and Comi, G. (2012). Influence of specific fermentation conditions on natural microflora of pomace in "grappa" production. *World Journal of Microbiology and Biotechnology*, 28, 1747-1759.

Iida, Y., Tominaya, Y., and Sugawara, R. (1981). Attractiveness of methylcyclohexyl n-alkanoates to the German cockroach. *Agricultural Biology and Chemistry*, 45(2), 469-473.

Isono, N., Hayakawa, H., Usami, A., Mishima, T., and Hisamatsu, M. (2012). A Comparative study of ethanol production by *Issatchenkia orientalis* strains under stress conditions. *Journal of Bioscience and Bioengineering*, 113(1), 76-78.

Iwashina, T. (2003). Flavonoid function and activity to plants and other organisms. *Biological Sciences in Space*, 17(1), 24-44.

Izhaki, I. (2002). Emodin – a secondary metabolite with multiple ecological functions in higher plants. *New Phytologist*, 155, 205-217.

Jemal, M. (2000). High throughput quantitative bioanalysis by LC/MS/MS. *Biomedical Chromatography*, 14, 422-429.

Jiang, H., Zhou, L., Zhang, J. M., Doug, H. F., Hu, Y. Y., and Jiang, M. S. (2008). Potential of *Periplaneta fuliginosa* densovirus as a biocontrol agent for smoky-brown cockroach, *P. fuliginosa*. *Biological Control*, 46, 94-100.

Jiang, J. (1995). Volatile metabolites produced by Kluyveromyces lactis and their changes during fermentation. *Process Biochemistry*, 30(7), 635-640.

Johnson, D. W. (2005). Contemporary clinical usage of LC/MS: Analysis of biologically important carboxylic acids. *Clinical Biochemistry*, 38, 351-361.

Jung, P. P., Friedrich, A., Souciet, J., Louis, V., Potier, S., de Montigny, J., and Schacherer, J. (2010). Complete mitochondrial genome sequences of the yeast *Pichia farinose* and comparative analysis of closely related species. *Current Genetics*, 56, 507-515.

Kalyani, A., Prapulla, S. G., and Karanth, N. G. (2000). Study on the production of 6-pentyl-α-pyrone using two methods of fermentation. *Applied Microbial Biotechnology*, 53, 610-612.

Kanakis, C. D., Daferera, D. J., Tarantilis, P. A., and Polissiou, M. G. (2004). Qualitative determination of volatile compounds and quantitative evaluation of safranal and 4-Hydroxy-2,6,6-trimethyl-1-cyclohexane-1-carboxaldehyde (HTCC) in Greet saffron. *Journal of Agricultural and Food Chemistry*, 52, 4515-4521.

Kasthuri, T., Gowdhaman, D., and Ponnusami, V. (2012). Production of ethanol from water hyacinth (*Eichhornia crassipes*) by *Zymomonas mobilis* CP4: Optimization studies. *Asian Journal of Scientific Research*, 5(4), 285-289.

Karimifar, N., Gries, R., Khaskin, G., and Gries, G. (2011). General food Semiochemicals attract omnivorous German cockroaches, *Blattella germanica*. *Agricultural and Food Chemistry*, 59, 1330-1337.

Katsuki, H., and Bloch, K. (1967). Studies on the biosynthesis of ergosterol in yeast. *The Journal of Biological Chemistry*, 242(2), 222-227.

Kaur, U., Oberoi, H. S., Bhargav, V. K., Sharma-Shivappa, R., and Dhaliwal, S. S. (2012). Ethanol production from alkali- and ozone-treated cotton stalks using thermotolerant *Pichia kudriavzevii* HOP-1. *Industrial Crops and Products*, 37(1), 219-226.

KEGG: Kyoto Encyclopedia of Gene and Genomes. Retrieve December 29, 2012 from http://www.genome.jp/kegg/

Kells, S. A. (2005). Bait aversion by German cockroaches (Dictyoptera: Blattellidee): The Influence and interference of nutrition. *Proceedings of the Fifth International Conference on Urban Pests*. P & Y Design Network, Malaysia: ICUP, 419-422.

Kim, J. H., and Mullin, C. A. (2007). An isorhamnetin rhamnoglycoside serves as a costimulant for sugars and amino acids in feeding responses of adult western corn rootworms.(*Diabrotica virgifera virgifera*) to corn (*zea may*) pollen. *Journal of Chemistry and Ecology,* 33, 501-512.

Kite, G. O., and Hetterschieid, W. L. A. (1997). Inflorescence odours of amorphophallus and Pseudodracontium (araceae). *Phytochemistry*, 46(1), 71-75.

Klose, C., Surma, M.A., Gerl, M.J., Meyenhofer, F., Shevchenko, A. and Simons, K. (2012). Flexibility of a eukaryotic lipidome – insights from yeast lipidomics. *PLOS ONE*. 7(4), e35063.

Koehler, P. G., Oi, F. M., and Branscome, D. (2007). Cockroaches and their management. University of Florida IFAS extension. Retrieved September 26, 2012 from www.edis.ifas.ufl.edu/ig082

Kooijman, S. A. L. M., Segel, L. A. (2005). How growth affects the fate of cellular Metabolites. *Bulletin of Mathematical Biology*, 67, 57-77.

Kotze, M. J., Jurgens, A., Johnson, S. D., and Hoffmann, J. H. (2010). Volatiles associated with different flower stages and leaves of *Acacia Cyclops* and their potential role as host attractants for *Dasineura dielsi (Diptera: Cecidomyiidae*). *South African Journal Botany*, 76, 701-709.

Krings, U., and Berger, R. G. (1998). Biotechnological production of flavors and fragrances. *Applied Microbiology and Biotechnology*, 49, 1-8.

Krokida, M. K., and Philippoulos, C. (2006). Volatility of apples during air and freeze drying. *Journal of Food Engineering*, 73, 135-141.

Kugimiya, S., Nishida, R., Kuwahara, Y. and Sakuma, M. (2002). Phospholipid composition and pheromonal activity of nuptial secretion of the male German cockroach, *Blattella germanica*. *Entomologia Experimentalis et Applicata*. 104, 337-344.

Kurtzman, C. P., Smiley, M. J., and Johnson, C. J. (1980). Emendation of the genus Issatchenkia Kudriavzev and comparison of species by deoxyribonucleic acid reassociation, mating reactions, and ascospore ultrastructure. *International Journal of Systematic Bacteriology*, 30(2), 503-513.

Lacerda, I. C. A., Miranda, R. L., Borelli, B. M., Numes, A. C., Nardi, R. M. D., Lachance, M., and Rosa, C. A. (2005). Lactic acid bacteria and yeasts associated with spontaneous fermentations during the production of sour cassava starch in Brazil. *International Journal of Food Microbiology*, 105, 213-219.

Lakshmanan, D., and Radha, K. V. (2012). An effective quantitative estimation of lovastatin from Pleurotus ostreatus using UV and HPLC. *International Journal of Pharmacy and Pharmaceutical Sciences*, 4(4), 462-464.

Landrault, N., Larronde, F., Delaunay, J., Castagnino, C., Vercauteren, J., Merillon, J., Gasc, F., Cros, G., and Teissedre, P. (2002). Levels of stilbene oligomers and astilbin in French varietal wines and in grapes during noble rot development. *Journal of Agricultural and Food Chemistry*, 50, 2046-2052.

Larsen, T. O., and Frisvad, J. C. (1995). Characterization of volatile metabolites from 47 Penicillium taxa. *Mycology Research*, 99(10), 1153-1166.

Larue, F., Lafon-Lafourcade, S., and Ribereau-Gayon, P. (1980). Relationship between the sterol content of yeast cells and their fermentation activity in grape must. *Applied and Environmental Microbiology*, 39(4), 808-811.

LeBouf, R. F., Schuckers, S. A., and Rossner, A. (2010). Preliminary assessment of a model to predict mold contamination based on microbial volatile organic compound profiles.*Science of the Total Environment*, 408, 3648-3653.

Lee, P. R., Ong, Y. L., Yu, B., Curran, P., and Liu, S. Q. (2010). Profile of volatile compounds during papaya juice fermentation by a mixed culture of *Saccharomyces cerevisiae* and *Williopsis saturnus*. *Food Microbiology*, 27, 853-861.

Lodolo, E. J., Kock, J. L. F., Axcell, B. C., and Brooks, M. (2008). The yeast *Saccharomyces cerevisiae* – the main character in beer brewing. *FEMS Yeast Research*, 8, 1018-1036.

Longo, M. A., and Sanroman, M. A. (2006). Production of food aroma compounds. *Food Technology Biotechnology*, 44(3), 335-353.

Lorenzo, M. G., Manrique, G., Pires, H. H. R., de Brito Sanchez, M. G., Diotaiuti, L., and Lazzari, G. R. (1999). Yeast culture volatiles as attractants for *Rhodius prolixus*: Electroantennogram responses and captures in yeast-baited traps. *Acta Tropica*, 72,119-124.

Loscos, N., Hernandez-Orte, P., Cacho, J., and Ferreira, V. (2007). Release and formation of varietal aroma compounds during alcohol fermentation from nonfloral grape odorless flavor precursors fractions. *Journal of Agricultural and Food Chemistry*, 55, 6674-6684.

Lucas, J. R., and Invest, J. F. (1993). Factors involved in the successful use of hydramethylnon baits in household and industrial pest control. *Proceedings of the first International Conference in Urban Pests*, 99-106.

Luo, W., D'Angelo, E. M., and Coyne, M. S. (2007). Plant secondary metabolites, biphenyl and hydroxypropyl-β-cyclodextrin effects on aerobic polychlorinated biphenyl removal and microbial community structure in soils. *Soil Biology and Biochemistry*, 39, 735-743.

Luo, B., Groenk, K., Takors, R., Wandrey, C., and Oldiges, M. (2007). Simultaneous determination of multiple intracellular metabolites in glycolysis, pentose phosphate pathway and tricarboxylic acid cycle by liquid chromatography – mass spectrometry. *Journal of Chromatography A*, 1147, 153-164.

Maffei, M. E. (2010). Sites of synthesis, biochemistry and functional role of plant volatiles. *South African Journal of Botany*, 76, 612-631.

Magan, N., Pavlon, A., and Chrysanthakis, I. (2001). Milk-sence: a volatile sensing system recognizes spoilage bacteria and yeasts in milk. *Sensors and Actuators*, B 72, 28-34.

Magan, N., and Evans, P. (2000). Volatiles as an indicator of fungal activity and differentiation between species, and the potential use of electronic nose technology for early detection of grain spoilage. *Journal of Stored Products Researc*h, 36, 319-340.

Maghsoodi, V., Razavi, J., and Yaghmaei, S. (2009). Production of chitosan by submerged fermentation from *Aspergillus niger*. *Transactions C: Chemistry and Chemical Engineering*, 16(2), 145-148.

Monobe, M., Arimoto-Kobayashi, S., and Ando, K. (2003). B-Pseudouridine, a beer component, reduces radiation-induced chromosome aberrations in human lymphocytes. *Mutation Research,* 538, 93-99.

Mas, S., Villa-Boas, S. G., Hansen, M. E., Akesson, M., and Nielsen, J. (2006). A comparison of direct infusion MS and GC-MS for metabolic footprinting of yeast mutants. *Biotechnology and Bioengineering*, 96(5), 1014-1022.

Matuszewski, B. K., Constanzer, M. L., and Chavez-Eng, C. M. (1998). Matrix effect in quantitative LC/MS/MS analysis of biological fluids: A method for determination of finasteride in human plasma at pictogram per milliliter concentrations. *Analytical Chemistry*, 70, 882-889.

Meinwald, J. (1990). Alkaloids and isoprenoids as defensive and signaling agents among insects. *Pure & Applied Chemistry*, 62(7), 1325-1328.

Morao, A., Brites Alves, A. M., and Cardoso, J. P. (2001). Ultrafiltration of demethylchlrotetracycline industrial fermentation broths. *Separation and Purification Technology*, 22-33, 459-466.

Mukherjee, S., Zha, X., Tabas, I., and Maxfield, F. R. (1998). Cholesterol distribution in living cells: Fluorescence imaging using dehydroergosterol as a fluorescent cholesterol analog. *Biophysical Journal*, 75, 1915-1925.

Nalyanya, G., and Schal, C. (2001). Evaluation of attractants for monitoring populations of the German cockroach (*Dictyoptera Blattellidae*). *Journal of Economic Entomology*, 94(1), 208-214.

Nevoigt, E. (2008). Progress in metabolic engineering of *Saccharomyces cerevisiae*. *Microbiology and Molecular Biology Review*, 72(3), 379-412.

N'guessan, K. F., Brou, K., Jacques, N., Casaregola, S., and Dje, K. M. (2011). Identification of yeasts during alcoholic fermentation of *tchapalo*, a traditional sorghum beer from Cote d'Ivoire. *Antonie van Leeuwenhoek*, 99, 855-864.

Nguyen, M. T., and Ranamukhaarachchi, S. L. (2010). Soil-borne antagonists for biological control of bacterial wilt disease caused by *Ralstonia solanacearum* in tomato and pepper. *Journal of Pathology*, 92(2), 395-406.

Nguyen, M. T., Ranamukhaarachchi, S. L., and Hannaway, D. B. (2011). Efficacy of antagonistic strains of *Bacillus megaterium*, *Enterobacter cloacae*, *Pichia guilliermondii* and *Candida ethanolica* against bacterial wilt disease of tomato. *Journal of Phytology*, 3(2), 01-10.

Nishida, R., Enomoto, H., Shelly, T. E., and Ishida, T. (2009). Sequestration of 3-oxygenated α-ionone derivatives in the male rectal gland of the solanaceous fruit fly, *Bactrocera latifrons*. *Entomologi Experimentalis et Applicata*, 131, 85-92.

Norin, T. (2007). Semiochemicals for insect pest management. *Pure and Applied Chemistry*, 79, 2129-2136.

Nout, M. J. R., and Bartelt, R. J. (1998). Attraction of a flying mitidulid (*Carpohpilus humeralis*) to volatiles produced by yeasts grown on sweet corn and a corn-based medium. *Journal of Chemical Ecology*, 24(7), 1217-1239.

Nova, M. X. V., Schuler, A. R. P., Brasileiro, B. T. R. V., and Morais Jr., M. A. (2009).Yeast species involved in artisanal *cachaca* fermentation in three stills with different technological levels in Pernambuco, Brasil. *Food Microbiology,* 26, 460-466.

Nuobariene, L., Hansen, A. S., and Arneborg, N. (2012). Isolation and identification of phytase-active yeasts from sourdoughs. *LWT-Food Science and Technology*, 48,190-196.

Oberoi, H. S., Babbar, N., Sandhu, S. K., Dhahival, S. S., Kaur, U., Chadha, B. S., and Bhargav, V. K. (2012). Ethanol production from alkali-treated rice straw via simultaneous saccharification and fermentation using newly isolated thermotolerant *Pichiakudriavzevii* HOP-1. *Journal of Industrial Microbiology and Biotechnology*, 39, 557-566.

Ohvo-Rekila, H., Ramstedt, B., Leppimaki, P., and Slotte, J. P. (2002). Cholesterol interactions with phospholipids in membranes. *Progress in Lipid Research*, 41,66-97.

Olczak, M., and Guillen, E. (2006). Characterization of a mutation and an alternative Splicing of UDP-galactose transporter in MDCK-RCA cell line. *Biochemica et Biophysica Acta,* 1763, 82-92.

Oppliger, F.Y., Guerin, P.M. and Vlimant, M. (2000). Neurophysiological and Behavioural evidence for an olfactory function for the dorsal organ and a gustatory one for the terminal organ in *Drosophila melanogaster* larvae. *Journal of Insect Physiology*. 46, 135-144.

Pai, H. (2013). Multidrug resistant bacteria isolated from cockroaches in long-term care facilities and nursing homes. *Acta Tropica*, 125(1), 18-22.

Pajot, H. F., Delgado, O. D., de Figueroa, L. I. C., and Farina, J. I. (2011). Unraveling the decolourizing ability of yeast isolates from dye-polluted and virgin environments: an ecological and taxonomical review. *Antonie van Leeuwenhoek*, 99, 443-456.

Papalexandratou, Z., and De Vuyst, L. (2011). Assessment of the yeast species composition of cocoa bean fermentations in different cocoa-producing regions using denaturing gradient gel electrophoresis. *FEMS Yeast Research*, 11, 564-574.

Park, K. S., Lee, H. Y., Lee, S. Y., Kim, M., Kim, S. D., Kim, J. M., Yun, J., Im, D., and Bae, Y. (2007). Lysophosphatidylethanolamine stimulates chemotactic migration and cellular invasion in SK-OV3 human ovarian cancer cells: Involvement of pertussis toxin-sensitive G-protein coupled receptor. *FEB Letters*, 581, 4411-4416.

Park, J. P., Kim, S. W., Hwang, H. J., and Yun, J. W. (2000). Optimization of submerged culture conditions for the mycelia growth and exo-biopolymer production by *Cordyceps militaris*. *Letters in Applied Microbiology*, 33, 76-81.

Perrut, M. (2000). Supercritical fluid applications: Industrial development and economic issues. *Industrial and Engineering Chemistry Research*, 39, 4531-4535.

Pickersky, E., and Gershenzo, J. (2002). The formation and function of plant volatile: Perfurme for pollinator attraction and defense. *Current Opinion in Plant Biology*, 5, 237-243.

Piskur, J., Rozpedowska, E., Polakova, S., Merico, A., and Compagno, C. (2006). How did *Saccharomyces* evolve to become a good brewer? *Trends in Genetics*, 22(4), 183-186.

Pinson, B., Vaur, S., and Seagot, I (2009). Metabolic intermediates selectively stimulate transcription factor interaction and modulate phosphate and purine pathways.*Genes and Development*, 23, 1399-1407.

Pontes, M., Pereira, J., and Camara, J. S. (2012). Dynamic headspace solid-phase microextraction combined with one-dimensional gas chromatography-mass spectrometry as a powerful tool to differentiate banana cultivars based on their volatile metabolic profile. *Food Chemistry*, 134, 2509-2520.

Quesada-Moraga, E., Santos-Quiros, R., Valverde-Garcia, P., and Santiago-Alvarez, C. (2004). Virulence, horizontal transmission, and sublethal reproductive effects of *Metarhizium anisopliae* (Anamorphic fungi) on the German cockroach (Blattodea: Blattellidae). *Journal of Invertebrate Pathology*, 87, 51-58.

Ragaert, P., Devlieghere, F., Loos, S., Dewulf, J., Van Langenhove, H., and Debevere, J. (2006). Metabolite production of yeasts on a strawberry-agar during storage at 7°C in air and low oxygen atmosphere. *Food Microbiology*, 23, 154-161.

Reddy, L. V. A., and Reddy, O. V. S. (2011). Effect of fermentation conditions on yeast growth and volatile composition of wine produced from mango (Mangifera indica L.) fruit juice. *Food and Bioproducts Processing*, 89, 487-491.

Regnier, F. E., and Law, J. H. (1968). Insect pheromones. *Journal of Lipid Research*, 9, 541-551.

Rivault, C. (1989). Spatial distribution of the cockroach, *Blattella germanica*, in a swimming-bath facility. *Entomologia Experimentalis et Applicata*, 53,247-255.

Rodriguez-Naranjo, M. I., Gil-Izquierdo, A., Troncoso, A. M., Cantos-Villar, E., and Garcia-Parrilla, M. C. (2011). Melatonin is synthesised by yeast during alcoholic fermentation in wines. *Food Chemistry*, 126, 1608-1613.

Romano, P., Fiore, C., Paraggio, M., Caruso, M., and Capece, A. (2003). Function of yeast species and strains in wine flavor. *International Journal of Food Microbiology*, 86(1- 2), 169-180.

Rossouw, D., Du Toit, M., and Bauer, F. F. (2012). The impact of co-inoculation with *Oenococcus oeni* on the transcriptome of *Saccharomyces cerevisiae* and on the flavor-active metabolite profiles during fermentation in synthetic must. *Food Microbiology*, 29(1), 121-131.

Rowan, D. D. (2011). Volatile metabolites. *Metabolites*, 1(1), 41-63.

Rust, M. K., and Reierson, D. A. (2007). Cockroaches. University of California Agricultural and Natural Resources. Retrieved December 28, 2012 from http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn7467.html

Sadoudi, M., Tourdot-Marechal, R., Rousseaux, S., Steyer, D., Gallardo-Chacon, J., Ballester, J., Vichi, S., Guerin-Schneider, R., Caixach, J., and Alexandre, H. (2012).Yeast-yeast interactions revealed by aromatic profile analysis of Sauvignon Blanc wine fermented by single or co-culture of non-*Saccharomyces cerevisiae* and *Saccharomyces* yeasts. *Food Microbiolog*y, 32, 243-253.

Saghatelian, A., Trauger, S. A., Want, E. J., Hawkins, E. G., Siuzdak, G., and Cravatt, B. F. (2004). Assignment of endogenous substrates to enzymes by global metabolic profiling. *Biochemistry*, 43, 14332-14339.

Sampranpiboon, P., Jiraratananon, R., Uttapap, D., Feng, X., and Huang, R. Y. M. (2000).Separation of aroma compounds from aqueous solutions by pervaporation using polyctylmetyl siloxane (POMS) and polydimethyl siloxane (PDMS) membranes. *Journal of Membrane Science*, 174, 55-65.

Sasaki, K., and Takahashi, T. (2002). A flavonoid from Brassica rapa flower as the uv-absorbing nectar guide. *Photochemistry*, 61, 339-343.

Scalcinati, G., Otero, J. M., van Vleet, J. R. H., Jeffries, T. W., Olsson, L., and Nielsen, J. (2012). Evolutionary engineering of *Saccharomyces cerevisiae* for efficient aerobic xylose consumption. *FEMS Yeast Research*, 12, 582-597.

Scherkenbeck, J., Nentwig, G., Justus, K., Lenz, J., Gondol, D., Wendler, G., Dambach, M.,Nischk, F. and Graef, C. (1999). Aggregation agents in German cockroach (*Blattella germanica*): Examination of efficacy. *Journal of Chemical Ecology*. 25(5), 1105-1119.

Schugerl, K. (2000). Integrated processing of biotechnology products. *Biotechnology*

Advances, 18, 581-599.

Schwalbe, C. P., and Mastro, V. C. (1988). Multispecific trapping techniques for exotic-pest detection. *Agriculture, Ecosystems and Environment*, 21, 43-51.

Serandour, J., Reynaud, S., Willison, J., Patouraux, J., Gaude, T., Ravanel, P., Lemperiere, G., and Raveton, M. (2008). Ubiquitous water soluble molecules in aquatic plant exudates determine specific insect attraction. *PLoS One*, 3(10), e3350, doi: 10.371.

Seto, Y. (1994). Determination of volatile substances in biological samples by headspace gas chromatography. *Journal of Chromatography A*, 674, 25-62.

Shori, A. B. (2012). Comparative study of chemical composition , isolation and identification of micro-flora in traditional fermented camel milk products: G*ariss, suusac, and shubat*. *Journal of the Saudi Society of Agricultural Sciences*, 11, 79-88.

Singh, R., Vadlani, P. V., Harrison, M. L., Bennett, G. N., and San, K. Y. (2008). Aerobic production of isoamyl acetate by overexpression of the yeast alcohol acetyl-transferases AFT1 and AFT2 in *Escherichia coli* and using low cost fermentation ingredients. *Bioprocess Biosystem Engineering Journal*, 31, 299-306.

Styger, G., Prior, B., and Baur, F. F. (2011). Wine flavor and aroma. *Journal of Industrial Microbiology and Biotechnology*, 38, 1145-1159.

Suh, S., Blackwell, M., Kurtzman, C. P., and Lachance, M. (2006). Phylogenetics of *Saccharomycetales*, the ascomycete yeasts. *Mycologia*, 98(6), 1006-1017.

Sunesson, A., Vaes, W. H. J., Nilsson, C., Blomquist, G., Anderson, B., and Carlson, R. (1995). Identification of volatile metabolites from five fungal species cultivated in two media. *Applied and Environmental Microbiology*, 61(8), 2911-2918.

Swiegers, J. H., Bartowsky, E. J., Henschke, P. A., and Pretorius, I. S. (2005).

Microbial modulation of wine aroma and flavour. *Australian Journal of Grape and Wine Research*, 11, 139-173.

Tao, B. Y. (2007). Industrial Applications for Plant Oils and Lipids. *Bioprocessing for Value-Added Products from Renewable Resources*. Shang-Tian Yang (Editor). 611-627.

Teo, H. T. R., and Saha, B. (2004). Heterogeneous catalyzed esterification of acetic acid with isoamyl alcohol: kinetic studies. *Journal of Catalysis*, 228, 174-182.

Ting, A. S. Y., Mah, S. W., and Tee, C. S. (2010). Identification of volatile metabolites from fungal endophytes with biocontrol potential towards *Fusarium oxysporum* F. sp. cubense Race 4. *American Journal of Agricultural and Biological Sciences*, 5(2), 177-182.

Tirranen, L. S., and Gitelson, I. I. (2006). The role of volatile metabolites in microbial Communities of the LSS higher plant link. *Advances in Space Research*, 38, 1227-1232.

Tsiftsoglou, A. S., Tsamadou, A. I., and Papadopoulou, L. C. (2006). Heme as key regulatorof major mammalian cellular functions: Molecular, cellular, and pharmacological aspects. *Pharmacology and Therapeutics*, 111, 327-345.

Trhlin, M. and Rajchard, J. (2011). Chemical communication in the honeybee (*Apis mellifera* L.): a review. *Veterinarni Medicina*. 56(6), 265-273.

Tsakiris, A., Koutinas, A. A., Psarianos, C., Kourkoutas, Y., and Bekatorou, A. (2010). A New process for wine production by penetration of yeast in uncrushed frozen grapes.*Applied Biochemstry and Biotechnology*, 162, 1109-1121.

Tsuji, H. and Ono, S. (1970). Glycerol and related compounds as feeding stimulants for cockroaches. *Japanese Journal of Sanitary Zoology*. 21(3), 149-156.

University of Leeds, Brewing and Microbiology, Virtual Labs @ Leeds. Retrieved January 17, 2013 from www.virtual-labs.leeds.ac.uk/brewing/fermentation

Vaishnav, P., and Demain, A. L. (2010). Unexpected applications of secondary metabolites. *Biotechnology Advances*, 29, 223-229.

Valdez, A. V., Garcia, L. S., Kirchmayr, M., Rodriguez, P. R., Esquinca, A. G., Coria, A. and Mathis, A. G. (2011). Yeast communities associated with Artisanal mescal fermentations from Agave salmiana. *Antonie van Leeuwenhoek*, 100, 497-506.

Vandamme, E. J. (2003). Bioflavours and fragrances via fungi and their enzymes. *Fungal Diversity*, 13, 153-166.

Verpoorte, R., Contin, A., and Memelink, J. (2002). Biotechnology for the production of plant secondary metabolites. *Phytochemistry Reviews*, 1, 13-25.

Vukovic, G., Shtereva, D., Bursic, V., Mladenova, R., and Lazic, S. (2012). Application of GC-MSD and LC-MS/MS for the determination of priority pesticides in baby foods in Serbia market. *LWT-Food Science and Technology*, 49, 312-319.

Walse, S. S., Lu, F., and Teal, P. E. A. (2008). Glucosylated suspensionsides, water-soluble pheromone conjugates from the oral secretions of male anastrepha suspense. *Journal of Natural Products*, 71, 1726-1731.

Wang, X. (2004). Lipid signaling. *Current Opinion in Plant Biology*, 7, 329-336.

Wang, C., and Bennett, G. W. (2006). Comparison of cockroach traps and attractants for monitoring German cockroaches (*Dictyoptera Blattellidae*). *Environmental Entomology*, 35(3), 765-770.

Wu, H., Lee, H., Horng, S., and Berec, L. (2007). Modeling population dynamics of two cockroach species: Effect of the circadian clock, interspecific competition and pest control. *Journal of Theoretical Biology*, 249, 473-486.

Wu, S., Jin, Z., Kim, J. M., Tong, Q., and Chen, H. (2009). Downstream processing of pullulan from fermented broth. *Carbohydrate Polymers*, 77, 750-753.

Xia, H. J., and Yang, G. (2005). Inositol 1,4,5-triphosphate 3-kinases: Functions and regulations. *Cells Research*, 15(2), 83-91.

Xiu, Z., and Zeng, A. (2008). Present state and perspective of downstream processing of Biologically produced 1,3-propanediol and 2,3-butanediol. *Applied Microbial Biotechnology*, 78, 917-926.

Yoon, S., Mukerjea, R., and Robyt, J. F. (2003). Specificity of yeast (*Saccharomyces cerevisiae*) in removing carbohydrates by fermentation. *Carbohydrate Research*, 338,1127-1132.

Zabriskie, T. M., and Jackson, M. D. (2000). Lysine biosynthesis and metabolism of fungi.*Natural Product Reports*, 17, 85-97.

Zhang, L., Hach, A. and Wang, C. (1998). Molecular mechanism governing heme signallingin yeast: a higher-order complex mediates heme regulation of the transcriptional activator HAP1. *Molecular and Cellular Biology*. 18(7), 3819-3828.

Zheng, X., Yan, Z., Han, B., Zwietering, M. H., Samson, R. A., Boekhout, T., and Nout, M. J. R. (2012). Complex microbiota of a Chinese “Fen” liquor fermentation starter (*Fen-Daqu*), revealed by culture-dependent and culture-independent methods. *Food Microbiology*, 31, 293-300.

Zhou, B., Yuan, J., Zhou, Y., Yang, J., James, A. W., Nair, U., Shu, X., Liu, W., Kanangat, S., and Yoo, T. J. (2012). The attenuation of cockroach allergy by DNA vaccine encoding cockroach allergen Bla g 2. *Cellular Immunology*, 278, 120-124.