Yogurt is a healthy food and it has become a good candidate for fortification with many healthful ingredients including fruits, herbs, prebiotics, probiotics, and omega-3 fatty acids. Whatever the fortification strategies, it is essential that the finished product retain a desirable taste, becomes more nutritious and has long shelf life. The present study investigated the benefits green tea would bring to increase yogurt properties by virtue of the high levels of flavonoids which can protect cells and tissues from oxidative damage by scavenging oxygen-free radicals. The presence of green tea would however affect yogurt bacteria fermentation of milk and subsequently the typical fermentation products responsible for the physicochemical properties (e.g. organic acids), nutritional (e.g. digested protein and carbohydrate) and functional (e.g. bioactive peptides, organic acids, viable lactic acid bacteria) values of yogurt. On the other hand changing acidic environment and microbial metabolic activities are expected to exert profound effects on the breakdown of green tea phytochemical contents and subsequently any biological activities associated with these compounds.

Milk was incubated (41°C) with starter culture (SC) in the presence of two types of green tea (MGT and JGT) until pH of yogurt reached 4.5. The resulting green-tea-yogurts were evaluated with respect to changes in antioxidant activity, phenolic compounds, the growth of lactic acid bacteria (LAB), acidification, exopolysaccharide (EPS) content, organic acids and rheological characteristics of yogurt during fermentation and storage at 4°C. The total phenolic content (TPC) was higher in MGT than those from JGT leaves infusion. Major phenolic compounds (gallocatechin, epicatechin, epigallocatechin gallate, quercetin-rhamnosylgalactoside, and kaempferol-3-O-rutinoside) in MGT leaves infusion were higher in those JGT leaves infusion. Diphenyl picrylhydrazyl (DPPH, %) and ferric reducing antioxidant power (FRAP, mmol/L) methods were used to evaluate the antioxidant capacity of yogurts. Inhibition of DPPH oxidation was highest for MGTY followed by JGTY and PY whereas FRAP value showed highest (p>0.05) ferric reduction power for MGTY followed by JGTY and PY. Viable *S.thermophilus* and *Lactobacillus spp.* counts in yogurt were highest in MGTY followed by JGTY and PY. Proteolysis in green tea yogurts increased with increasing fermentation time resulting in highest OPA
values for MGTY followed by PY at pH 4.5. Viable cells count (VCC) of *S. thermophilus spp.* increased by day 7 of storage with highest number present in MGTY followed by JGTY and PY. *Lactobacilus* spp. VCC decreased gradually for all yogurts during the 28 days of storage. Maximum DPPH inhibition by yogurts was shown on day 7 of storage by MGTY followed by JGTY and PY. The addition of green tea increased the FRAP values in MGTY which was 3 fold higher than JGTY and PY. Four major compounds were detected in green tea yogurts (quercetin-rhamnosyl, gallocatechin, kaempferol-3-rutinoside and epicatechin) with higher amounts present in MGTY than in JGTY but these tend to diminish by 28 days of refrigerated storage. The presence of green tea resulted in higher score recorded for overall appearance, colour, aroma and flavor in MGTY and JGTY compared with PY. However green tea yogurts showed more fluid like characteristics with distinct pseudo plastic properties and lesser ability to resist deformation upon applied shear. The presence of green tea during fermentation of milk increased the radical scavenging activities of yogurt and it stimulated the growth of both *S. thermophilus* and *L. bulgaricus* resulting in increased proteolysis of milk protein, acidification, enzymes activity and organoleptic properties. The catechin-related compounds, despite being not stable during refrigerated storage and had negative effects on rheology, have promising biological effects in increasing the nutritional and functional properties of yogurt.
Yogurt adalah makanan yang sihat dan ia menjadi perantara yang baik diperkaya dengan pelbagai ramuan seperti buah-buahan, herba, prebiotik, probiotik dan asid lemak omega. Teramatlah penting, walau apa sahaja strategi pemerka yang baik, memastikan produk terbentuk itu menjadi lebih berkhasiat dan tahan lama dalam simpanan. Kajian ini meneliti manfaat-manfaat yang boleh dibawa teh hijau dalam usaha meningkat kandungan yogurt hasil kebaikan flavonoid tinggi yang boleh melindungi sel-sel dan tisu dari kerosakan oksidatif akibat radikal-radikal bebas oksigen. Kehadiran teh hijau ini bagaimanapun akan mempengaruhi penapaian susu dan seterusnya produk-produk penapaian lazim bertanggungjawab ke atas ciri-ciri kimia-fizik (contoh: asid-asid organik), nilai-nilai nutrisi (contoh: kehadaman protein dan karbohidrat) dan fungsi (seperti peptida-peptida bioaktif, asid-asid organik, bakteria laktik asid hidup) yogurt. Sebaliknya perubahan sekitaran berasid dan aktiviti-aktiviti metabolik mikrob dijangka memberi kesan-kesan jelas ke atas peleraian kandungan fitokimia teh hijau dan seterusnya aktiviti-aktiviti biologi berkaitan sebatian-sebatian ini. Susu dieram (41°C) dengan bakteria pemula dalam kehadiran dua jenis teh hijau (MGT dan JGT) sehingga pH yogurt mencecah 4.5. Yogurt-TEH hijau terhasil telah dinilai merujuk kepada perubahan dalam aktiviti antioksidan, sebatian-sebatian fenolik, pertumbuhan bakteria asid laktik, pengasidan, kandungan eksopolisakarida, asid-asid organik dan ciri-ciri reologi yogurt semasa penapaian dan penyimpanan pada 4°C. Jumlah kandungan fenol adalah lebih tinggi dalam MGT berbanding daripad JGT. Sebatian fenolik utama (gallocatechin, epicatechin, epigallocatechin gallate, quercetin-rhamnosylgalactoside, kaempferol-3-O-rutinoside) dalam MGT adalah lebih tinggi daripada yang diperolehi dalam JGT. Kaedah-kaedah difenilpikrilhidrazil (DPPH,%) dan kuasa pengurangan antioksidan ferrik (mmol / L) diguna untuk menilai kapasiti antioksidan yogurt. Perencatan oksidasi DPPH adalah tertinggi untuk yogurts-MGT (MGTY) diikuti yogurts-JGT (JGTY) dan yogurts-biasa (PY) (39.18 ± 0.77, 31.19 ± 0.14 dan 17.43 ± 0.21% masing-masing) manakala nilai-nilai FRAP menunjukkan kuasa penurunan ferrik tertinggi bagi MGTY diikuti JGTY dan PY. *S. thermophilus* dan *Lactobacillus spp.* hidup dalam yogurt adalah tertinggi dalam MGT (119.1±0.98x10^6 and 15.21±0.70 x10^8 cfu ml^-1 masing-masing) diikuti oleh JGT (121.34 ± 1.43 x10^6 and 11.06±1.7 x10^8 cfu ml^-1 masing-masing) dan PY (104.65± 2.7 x10^6 and
Proteolisis dalam yogurt-yogurt teh hijau meningkat seiringan dengan peningkatan masa penapaian menyebabkan kepekatan nilai OPA tertinggi (p <0.05) bagi MGT diikuti JGT dan PY (22.4 ± 0.5, 18.11 ± 0.23 dan 9.22 ± 1.0 mg / mL masing-masing) di pH 4.5. Kiraan sel hidup (VCC) *S. thermophilus spp.* meningkat menjelang simpanan dingin hari ke-7 dengan bilangan tertinggi dalam MGT diikuti JGT dan PY (138.1±0.48, 129.34±0.87 and 110.22±0.99 x 10^6 cfu ml^-1 masing-masing). VCC *Lactobacillus spp.* berkurang secara beransur-ansur untuk semua jenis yogurt sepanjang tempoh 28 hari simpanan dingin. Perencatan maksima DPPH oleh yogurt berlaku dihari ke-7 simpanan bagi MGT (42.23±1.5%) diikuti JGT dan PY (37.11± 1.15% and 24.19± 2.01% masing-masing). Tanbahan teh hijau meningkatkan nilai-nilai FRAP bagi MGT (14.19± 3.67 mmol/L) adalah bersamaan 3 kali ganda dari JGT (3.79 ± 1.06 mmol/L) berbanding PY (1.25± 0.45 mmol/L). Empat sebatian utama (quercetin-rhamnosyl, galloatechin, kaempferol-3-rutinoside dan epicatechin) telah dikesan dalam sampel yogurt teh hijau dengan kepekatan tertinggi didapati dalam MGT berbanding dengan JGT tetapi sebatian-sebatian ini cenderung menghilang menjelang 28 hari simpanan yogurt. Kehadiran teh hijau dalam yogurt menyebabkan skor lebih tinggi untuk penampilan keseluruhan, warna, aroma dan rasa bagi MGT dan JGT berbanding dengan PY. Bagaimanapun yogurt-yogurt teh hijau menunjukkan lebih ciri-ciri kecairan dengan ciri-ciri plastik-pseudo dan kurang keupayaan merintang deformasi apabila dikenakan ricihan. Kehadiran teh hijau semasa penapaian susu meningkatkan aktiviti-aktiviti pengaut radikal yogurt dan merangsang pertumbuhan kedua-dua *S. thermophilus* and *L. bulgaricus* menyebabkan meningkatnya proteolisis protein susu, pengasidan dan ciri-ciri organoleptik. Sebatian-sebatian berkait-katekin, walaupun tidak stabil semasa simpanan dingin dan memberi kesan negatif ke atas reologi, mempunyai potensi kesan-kesan biologi dalam meningkatkan ciri-ciri nutrisi dan fungsi yogurt.
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6.16 Major phenolic compounds in Japanese green tea yogurt (20µL) analyzed in day 14 of storage on 50mm x 1.1 mm, column C18 eluted

6.17 Major phenolic compounds in Japanese green tea yogurt (20µL) analyzed in day 21 of storage on 50mm x 1.1 mm, column C18 eluted

6.18 Major phenolic compounds in Japanese green tea yogurt (20µL) analyzed in day 28 of storage on 50mm x 1.1 mm, column C18 eluted

7.1 Viscosities of fresh plain, Malaysia green tea and Japanese green tea-yogurt

7.2 Viscosity for plain yogurt during storage

7.3 Viscosity of Malaysian green tea yogurt during storage

7.4 Figure 7.4 Viscosity of Japanese green tea yogurt during storage

7.5 Frequency sweep of fresh plain yogurt, Malaysia green tea yogurt and Japanese green tea yogurt

7.6 Frequency sweep for Malaysia’s green tea yogurt for 1st day, 7th day, 14th day, 21st day and 28th day

7.7 Frequency sweep for Japanese green tea yogurt during storage

7.8 Frequency sweep for plain yoghurt for 1st day, 7th day, 14th day, 21st day and 28th day

7.9 Amplitude sweep of fresh plain, Malaysia green tea and Japanese green tea

7.10 Amplitude sweep for plain yogurt during storage

7.11 Amplitude sweep for Malaysian green tea yogurt during storage
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ABBREVIATION

°C  Degree Celsius
%
μ  Micro
cfu  Colony forming unit
Da  Dalton
dH2O  Distilled water
DPPH  1,1-diphenyl-2-picrylhydrazyl
DRY  radical inhibition
EPS  Exopolysaccharide
etc  et cetera
FRAP  Ferric reducing/antioxidant power
g  Gram
G’  Storage modulus
G”  Loss modulus
GAE  Gallic acid equivalents
H  Hour
HCL  Hydrochloride acid
Hz  Hertz
HPLC  High performance liquid chromatography
i.e.  For example
JGT  Japanese Green Tea
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>JGTY</td>
<td>Japanese Green Tea Yogurt</td>
</tr>
<tr>
<td>L</td>
<td>Litre</td>
</tr>
<tr>
<td>LAB</td>
<td>Lactic Acid Bacteria</td>
</tr>
<tr>
<td>Lb</td>
<td>Lactobacillus delbrueckii ssp. Bulgaricus</td>
</tr>
<tr>
<td>Lactobacillus spp</td>
<td>L. acidophilus, L. bulgaricus, L. casei, L. delbrueckii, L. fermentum, L. plantarum, L. reuteri</td>
</tr>
<tr>
<td>LC-MS</td>
<td>Liquid Chromatography-Mass Spectrometry</td>
</tr>
<tr>
<td>MGT</td>
<td>Malaysian Green Tea</td>
</tr>
<tr>
<td>MGTY</td>
<td>Malaysian Green Tea Yogurt</td>
</tr>
<tr>
<td>min</td>
<td>Minute</td>
</tr>
<tr>
<td>mL</td>
<td>Millilitre</td>
</tr>
<tr>
<td>mmol</td>
<td>Millimol</td>
</tr>
<tr>
<td>nm</td>
<td>Nanometer</td>
</tr>
<tr>
<td>OPA</td>
<td>O-Phthalaldehyde</td>
</tr>
<tr>
<td>pH</td>
<td>Hydrogen ion concentration</td>
</tr>
<tr>
<td>rad/s</td>
<td>Radian per second</td>
</tr>
<tr>
<td>rpm</td>
<td>Revolutions per minute</td>
</tr>
<tr>
<td>ROS</td>
<td>Reactive Oxygen Species</td>
</tr>
<tr>
<td>ssp</td>
<td>Subspecies</td>
</tr>
<tr>
<td>TA</td>
<td>Titratable acid</td>
</tr>
<tr>
<td>TPC</td>
<td>Total Phenolic Content</td>
</tr>
<tr>
<td>UV</td>
<td>Ultra violet</td>
</tr>
<tr>
<td>VCC</td>
<td>Viable Cell Counts</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Definition</td>
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<tr>
<td>--------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>V</td>
<td>volume(s)</td>
</tr>
<tr>
<td>WHC</td>
<td>Water holding capacity</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
<tr>
<td>Wt</td>
<td>Weight</td>
</tr>
<tr>
<td>w/v</td>
<td>Weight per volume</td>
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</table>
List of publications and scientific presentations during PhD study:

**S. Amirdivani, & A.S. Baba (2011).** Changes in yogurt fermentation characteristics, and antioxidant potential and in vitro inhibition of angiotensin-1 converting enzyme upon the inclusion of peppermint, dill and basil. LWT - Food Science and Technology 44, 1458-1464


S. Amirdivani & A.S. Baba (2012). Effect of green tea (*Camellia sinensis*) on antioxidant properties of yogurts as evaluated by changes in polyphenolic compounds characterised by LC-MS/MS. University of Malaya (Presentation).