Themed collection - Chemistry Driven Economy

Themed Collection

Uplifting "Ceylon Tea" with Chemistry

Damayanthi Dahanayake

Principal Research Scientist, Petroleum and Lubricant Testing Laboratory, Industrial Technology Institute

Introduction

"Ceylon tea" is a globally reputed unique brand that has stayed true to its value and promise on pure quality, throughout decades. It is known for its high levels of catechins, and unmatched taste with specific aroma. In 2019, tea exports accounted for US$ 1.35 billion of income[1] to the national economy. as the fourth largest tea exporter in the world. Tea export will continue to be the key economic value adder to Sri Lankan economy not just from the revenue of exporting tea, but also from the large population that is directly and indirectly involved in the industry.

Even though some competitors like Kenya entered the export market later than us, they have still managed to build a strong footing in the global trade, by challenging Sri Lanka's ability to maintain its past success, Sri Lanka is no longer a cheaper tea producer in the global arena due to its cost of labor and production compared to other low cost global competition. Thereby Sri Lanka has strategically drifted (or in the midst of drifting) to high-quality value-added producer from its positioning as a low cost producer. In the recent past, similar economic evaluation was also evidenced in Sri Lanka's apparel industry with the rise of multiple apparel factories engaging niche and value added production with selected large scale producers in global value chains.

Gaining such repositioning as a unique brand of "Ceylon Tea", with a set of values added to it, is one of the key advantages of Sri Lankan tea industry. However, it is also evidenced that Sri Lanka has still a long way to go in terms of repositioning to claim a value added differentiated end product from a 'bulk tea' export as a commodity product. Countries such as UAE are identified as large exporters of tea simply due to their ability of importing, value addition and re-exporting such products.

With increasing health consciousness, tea is currently gaining an increasing demand on its medicinal value.[2] Ceylon Tea can re-position itself as a revived brand that focus on health, value addition and as a differentiated product on customer demand and convenience, while maintaining its pure quality with the brand promise. Such market repositioning is only possible with the industrial players, those who are capable of changing the game by bundling up with scientific research. This article is aimed to provide a conscious synopsis on the chemical components of tea with the potential new avenues towards the value addition of tea products.

Chemistry of tea leaf

The most important and characteristic components of tea leaf are the polyphenols in the cell sap, which undergo a series of chemical changes when the leaf is macerated during manufacture. These compounds are mainly the derivatives of gallic acid and catechin. From the polyphenolic category, flavonoids are the most abundant in tea flush. Structurally, flavonoids are 2-phenyl benzopyran based scaffolds. These compounds can be classified into six groups: flavones, flavanones, isoflavones, flavanols, flavonols and anthocyanidins.[3] Catechins are the major flavanols in tea. During the black tea manufacturing process, these compounds can be subjected to oxidative dimerisation or polymerisation. The two key enzymes in tea leaves are, polyphenol oxidase and peroxidase involved in oxidation of polyphenols. It contains minerals, biochemical intermediates, carbohydrates, proteins and lipids in small quantities.[4]

During the oxidative polymerization process in black tea processing, the least catechin content and highest theaflavins and thearubigin content was observed as compared to oolong and green tea. Flavonols (such as quercetin, kaemferol, myricetin and their glycosides) and anthocyanidins are also found in the flush in appreciable amounts, but they do not usually undergo a significant chemical change during black tea manufacturing process.

The free sugars found in tea shoots are glucose,

fructose, sucrose, raffinose and stachyose. Free sugars are responsible for the synthesis of catechins in tea shoots, which form heterocyclic flavour compounds during processing of black tea and contributing towards water-soluble solids in tea liquor. Cellulose, hemicellulose, pectins and lignins are responsible for the formation of crude fiber content in black tea. Theanine alone contributed around 60 per cent of total amino acid content. Amino acids are playing a major role in development of tea aroma and the taste during the processing of black tea.[5]

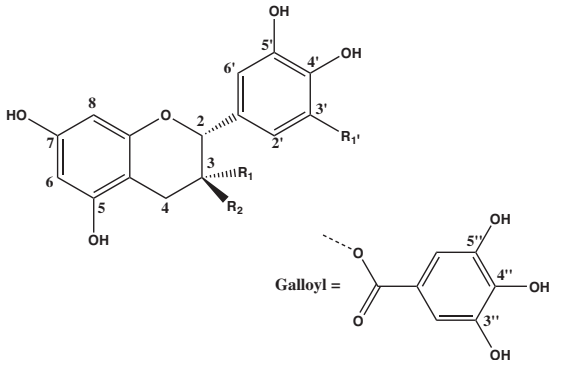
Chemical Composition of tea brew

The tea brew contains the hot water soluble components of made tea, which are extracted into boiling water used for infusion. Those chemical constituents are responsible for the taste and flavour as well as the nutritional value of the tea brew.

The main nutrients in tea brew are carbohydrates, fat and proteins. But their composition with respect to their contents in the food, are significantly less. Tea is also a rich source of dietary minerals, where potassium is prominent.

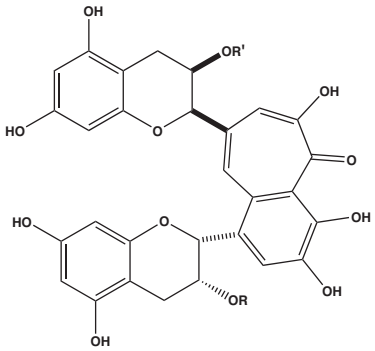
The tea brew also contains a significant amount of non-nutrient components, which have important biological functions other than energy production. The major non-nutrients are the polyphenols and the methylxanthine caffeine. Tea is unique in having huge amounts of polyphenols, which is up to 40 per cent of the solids extracted into the tea brew[4]. Catechins such as epicatechin (EC), epicatechin gallate (ECG) and epigallocatechin gallate (EGCG), are also responsible for the quality of the tea brew.[6]

The level of biotransformation of catechins into oxidized form during processing of tea leaves results in three main types of tea called black tea (fully oxidized), oolong tea (partially oxidized), and green tea (non-oxidized). As a major part of the catechins rearrange to theaflavins and thearubigins in black tea, individual catechins are less compared to green tea.



R_1	R_2	$R_{1'}$	
H	OH	H	(+)-Catechin (C)
OH	H	H	(-)-Epicatechin (EC)
OH	H	OH	(-)-Epigallocatechin (EGC)
Galloyl	H	H	(-)-Epicatechingallat (ECG)
Galloyl	H	OH	(-)-Epigallocatechingallat (EGCG)

Figure 1: Structure of catechins



Compound	R	R'
Theaflavin (TF1)	H	H
Theaflavin-3-monogallate (TF2a)	Galloyl	H
Theaflavin-3'-monogallate (TF2b)	H	Galloyl
Theaflavin-3,3'-digallate (TF3)	Galloyl	Galloyl

Figure 2: Structure of Theaflavins

Tea health benefits

Black tea has many important biological effects in favor to our health. In general, it is reported that drinking black tea is almost equal to drinking green tea in terms of the antioxidant properties.[7] Polyphenols and caffeine have beneficial pharmacological effects and give tea its unique dietary significance. Caffeine is a well-known stimulant acting on the central nervous system. It increases alertness and reduces feeling of drowsiness and fatigue. Polyphenols are strong antioxidants, which are mainly responsible for the beneficial effects of tea.

It is active against inflammation, and some types of cancer.[8,9] DNA damage and mutagenesis can be reduced by black tea. Preventing cardiovascular diseases, effecting gastrointestinal tract, lowering cholesterol level and influencing the hormonal balance, and antioxidant activity, improving bone mineral density are also reported as beneficial outcomes of tea.[10-12] With the inherent enzyme inhibiting and receptor blocking properties, tea is also being well documented for its antiviral activity[6]. Theaflavin activity against Herpes simplex virus type 1 and Sindbis virus, has been proven.[13]

Tea market products with value addition

Tea is mainly marketed as black tea, green tea and oolong tea. In Sri Lanka, we are mainly exporting black tea and a small quantity of green tea. There are other value added products such as tea bags, organic tea, flavoured tea, tea extracts, and instant tea. The beneficial polyphenolic compounds have a higher potential to value addition. Catechins, theaflavins, thearubigins can be used in value added products.

Tea bags with value addition:

Sri Lanka is popular in tea bag market today. This can be improved with our natural flavours like cinnamon, cardamom etc. Avoiding artificial flavours by moving towards natural components currently has a higher market trend. This will positively impact on the country's spice industry as well.

Value addition to the tea cup with other beneficial ingredients like *Garcinia*, can be a good marketing strategy for an international market.

Organic tea:

Heavy usage of pesticides and weedicides have become a serious problem in the tea industry today. The global concern to minimize the chemical residues in tea has been implemented by many countries with imposing minimum residue level (MRL) less than 0.1 ppm for most of the pesticides.[14] Organic tea is a good opportunity to obtain a high market share as some European countries and Japan are well concerned of the fertilizer and pesticide usage for tea. In order to achieve this, the tea gardens should be maintained as free from synthetic pesticides, weedicides or fertilizers. The resulting low yield could compensate for the high quality of organic tea in terms of market value. Presently some companies move towards manufacturing organic tea. Awareness programs highlighting the benefits of pure Ceylon tea would popularize our brands in the competitive global market.

Instant tea:

As the fast moving world ask for convenient food, tea also should be presented in different types other than the traditional black tea. Instant tea plays a major role in competing with other soft drinks globally. We can popularize these products with improved health properties. Addition of water soluble polyphenolic parts in high concentration and reduced sugar content would improve the quality of the tea. Instant tea can be produced with black tea, green tea, or oolong tea. The tea waste coming as a byproduct of the black tea process can be used for instant tea as well. Cold water insoluble part of instant tea which is also known as tea cream, can be used in many other applications explained below.

Tea in confectionary products:

The cold water insoluble tea has a higher amount of catechins which has numerous health benefits. This can be introduced in biscuits, and bakery products as a value added product. Cream added biscuits, cookies can be incorporated with tea polyphenols.

Tea in cosmetics:

The tea cream with catechins come as a waste product of the instant tea can be used in cosmetics such as soaps, facial wash, bath gel, body lotions etc. The saponins extracted by the tea waste can be used in soap production.

The catechins can be incorporated with liposomes and increase the efficiency of skin penetration. Anti-aging and anti-wrinkling cream formulations can also be prepared as value added products using the novel tool such as nanotechnology.

Nutraceutical applications with theaflavins:

Cellular damage caused by the reactive oxygen species (ROS) can be scavenged by tea polyphenols. These ROS accounts for aging, age related diseases and cancer.[15] The usage of antioxidant molecules to reduce oxidative stress appears to be an ideal approach for cancer prevention.[16] The antioxidant activity of theaflavins and other catechins can be used in nutraceutical drugs. The inherent weaknesses of polyphenols such as low solubility and unfavourable pharmacokinetics can be overcome with suitable carriers like liposomes.[17] Thus, there is a high potential area in nutraceutical industry for tea polyphenols as antioxidants.

Tea as a natural colorant

The unique colour of tea can be applied as a colouring agent in fabric and food industry. The natural dyes are accepted by environmentally concerned market segment over the world. Tea tannins can be extracted by waste tea and use as a colorant. It is reported that cellulose and jute fabric can be used to make a value addition with tea unique colours[18].

Summary

The brand value of Ceylon Tea can be carefully utilized to take Sri Lankan Tea to the next level in the global market. Exporting bulk tea as a commodity is not the way forward for Sri Lanka to compete with ever increasing low cost competition. Identifying the new avenues for value addition with proper understanding and usage of chemistry is important. The health benefits with tea compounds can be used in value added products such as instant tea, organic tea, confectionary and bakery products, nutraceutical products, cosmetics, and coloring agents. While in the past 150 years we managed to dominate this globally, speedy action from policy level to an end-to-end industry corroborated execution plan is essential to make sure its success in future years to come.

References:

1. Annual Report Central Bank, **2019**.
2. Wang, W. Y., Sun, C. X., Mao, L. K., Ma, P. H., Liu, F. G., Yang, J., & Gao, Y. X. The biological activities, chemical stability, metabolism and delivery systems of quercetin: A review. *Trends in Food Science & Technology*. **2016** *56*, 21–38.
3. Drynan, J. W., Clifford, M. N., Obuchowicz, J. and Kuhnert, N. The chemistry of low molecular weight black tea polyphenols. *Nat. Prod. Rep.* **2010**, *27*:417–462.
4. Modder, W. W. D. & Amarakoon, A. M. T., Tea and Health. Tea Research Institute, Talawakele, Sri Lanka, **2002**.
5. Roberts G. R., and Sanderson G. W. Changes undergone by free amino-acids during the manufacture of black tea. *Journal of the science of food and agriculture*. **1966**, volume 17, Issue 4.
6. Sharma, V, and Rao. L. J. M. A thought on the Biological Activities of Black Tea, *Critical Reviews in Food Science and Nutrition*, **2009**, *49*:379-404 (2009)
7. Leung, L. K., Su, Y., Chen, R., Zang, Z., Huang, Y. & Chen, Z. Y. Theaflavins in black and catechins in green tea are equally effective antioxidants. *J. Nutr.***2001**, *131*: 2248–2251.
8. Shi, S. T.; Wang, Z. Y.; Smith, T. J.; Hong, J. Y.; Chen, W. F.; Ho, C. T.; Yang, C. S. Effects of green tea and black tea on 4-(methylnitrosamine)-1-(3-pyridyl)-1-butanone bioactivation, DNA methylation and lung tumorigenesis in A/J mice. *Cancer Res.* **1994**, *54*, 4641-4647.
9. Wang, Z. Y.; Huang, M. T.; Lou, Y. R.; Xie, J. G.; Reuhl, K. R.; Newmark, H. L.; Ho, C. T.; Yang, C. S.; Conney, A. H. Inhibitory effects of black tea, green tea, decaffeinated black tea and decaffeinated green tea on ultraviolet B light-induced skin carcinogenesis in 7, 12-dimethylbenz(a)anthracene-initiated SKH-1 mice. *Cancer Res.* **1994**, *54*, 3428-3435.
10. Imai, K.; Nakachi, K. Cross sectional study of effects of drinking green tea on cardiovascular and liver disease. *Biochem. Med. J.* **1985**, *310*, 693-696
11. Kono, S.; Shinchi, K.; Ikeda, N.; Yanai, F.; Imanishi, K. Green tea consumption and serum lipid profile: a cross-sectional study in Northern Kyush. *Jpn. PreV. Med.* **1992**, *21*, 526-531.
12. Yang, M.-H.; Wang, C.-H.; Chen, H.-L. Green, oolong and black tea extracts modulate lipid metabolism in hyperlipidemic rats fed high-sucrose diet. *J. Nutr. Biochem.* **2001**, *12*, 14-20.

13. Alinede Oliveira , DerekPrince, Chih-YuLo, Lee H.Lee, Tin-ChunChu. Antiviral activity of theaflavin digallate against herpes simplex virus type 1 *Antiviral Research*. **2015**, Volume 118, Pages 56-67

14. G Gurusubramanian, A Rahman, M Sarmah, Somnath Ray, S Bora. Pesticide usage pattern in tea ecosystem, their retrospects and alternative measures. *J Environ Biol* **2008** Nov; *29*(6):813-26.

15. Fresco P, Borges F, Diniz C, Marques MPM. New insights on the anticancer properties of dietary polyphenols. *Med Res Rev* **2006**, *26*: 747–66.

16. Hou Z, Sang S, You H, et al. Mechanism of action of epigallocatechin-3-gallate: auto-oxidation-dependent inactivation of epidermal growth factor receptor and direct effects on growth inhibition in human esophageal cancer KYSE 150 cells. *Cancer Res* **2005**, *65*:8049–56.

17. Orazio Vittorio1, Manuela Curcio, Monica Cojoc, Gerardo F. Goya, Silke Hampel, Francesca Iemma, Anna Dubrovska, and Giuseppe Cirillo. Polyphenols delivery by polymeric materials: challenges in cancer treatment *Drug Deliv*, **2017**; *24*(1): 162–180.

18. Deo H T and B K Desai. Dyeing of cotton and jute with tea as a natural dye. *Coloration Technology* **2006**, *115*(7-8):224 – 227

Dr. Damayanthi Dahanayake *graduated from the Open University of Sri Lanka with a B.Sc. in Natural Sciences and obtained the GIC qualification from the College of Chemical Sciences, Institute of Chemistry Ceylon. She completed her PhD at the University of Peradeniya and has served at the Tea Research Institute of Sri Lanka, Sri Lanka Tea Board and Sri Lanka Institute of Nanotechnology (SLINTEC). She is currently serving as the Principal Research Scientist of the Petroleum and Lubricant Testing Laboratory at the Industrial Technology Institute.*

Themed Collection

Tyre Industry – Current Status and Future Opportunities

Hema Narangoda

Department of Materials and Mechanical Technology, Faculty of Technology, University of Sri Jayawardenapura

The global rubber products industry includes over 50,000 products that serve different consumer needs in diverse applications. The automotive sector, which comprises of tyres, tubes, and automotive rubber components, is the major contributor to over 60% of the total global rubber products. Besides the automotive sector, mining, medical & sports, aerospace, agriculture, construction, machinery, engineering and electrical appliance manufacturing industries are the major drivers of the rubber products industry. The global statistics for 2015 reveal that the rubber products industry has yielded total revenue estimated at US$ 400 billion by transforming nearly 27 million tons of natural and synthetic rubber into value added products and this value is expected to reach US$ 600 billion by 2025. However, the market value of raw rubber worldwide amounts to US$ 40.71 billion, and comparative products turn over shows a noteworthy value addition in the conversion process of rubber into products. The global scenario with respect to production and consumption of natural and synthetic rubber is given in Table 1. The data indicates that within a couple of decades the rubber consumption has increased by almost 76% and that shows a significant growth in the rubber products industry.

Rubber product manufacturing is a labour-intensive industry involving many "state-of-the-art" machinery. Technologies are continuously changing with the improvements that shift the production possibilities further. It is important to note that advances in technology are a result of innovations and innovative practices leading to product diversification and process improvements bringing in enhanced productivity. This is well established in the global rubber products industry through deep rooted research and development segments.

Impact of COVID – 19 Pandemic on the Rubber Industry

The coronavirus pandemic has had an adverse economic and social impact on all businesses around the world including the rubber industries as well. The