Chemical Compounds in Tea

Tea chemistry is complex. Just how complex? Well, on the bush, tea leaves contain thousands of chemical compounds, when they are processed, these compounds break down, form complexes and form new compounds. When we steep tea leaves, our senses are tingled by the thousands of volatile compounds (collectively known as the "aroma complex") from the tea liquor and the thousands of non-volatile compounds and the complexes between them, not all of which are water soluble, and the ones that are water soluble are soluble at a function of the properties of the water used for steeping like temperature, total dissolved solids, pH, etc.

So all of this makes it very difficult to generalize and say that x chemical is responsible for y taste. Many tea chemicals have been categorized into broad groups, and collectively we have some idea of what happens to these groups during processing and what flavors and aromas they are responsible for. As tea gains popularity, there is no doubt that more research will be done on tea chemistry and we'll have a clearer picture of what is going on chemically from the field to the cup.

Plant leaves are made up of mostly water, when they are removed from the plant they begin to wilt and lose water. Tea leaves are no exception to this. In the field, they are made up of mostly water, when they are plucked the leaves begin to lose water or wilt, a process called withering in the tea industry. As tea leaves wither, their cell walls begin to break down and the chemical components inside come in contact with oxygen and each another, spurring on a group of reactions we call oxidation. Over the years, tea producers have learned to control the natural tendency of tea leaves to wither and oxidize in order to produce a finished tea that has a desirable appearance, aroma, flavor, and taste using methods we'll refer to as tea processing.

Amazingly, for hundreds of years tea makers have produced drinkable teas using principles of withering and oxidation with no knowledge of the underlying chemistry. From what we know today, the most important compounds in fresh tea leaves responsible for producing teas with desirable appearance, aroma, flavor, and taste are: polyphenols, amino acids, enzymes, pigments, carbohydrates, methylxanthines, minerals and many volatile flavor and aromatic compounds. These components undergo changes during tea processing to produce what we'll

call a ‘finished’ or ‘made’ tea – one that has been processed and is ready for packaging or steeping. Let’s take a look at each of these compounds beginning with the most abundant, polyphenols.

Polyphenols

In steeped tea, polyphenols are largely responsible for astringency. The term polyphenol simply refers to a categorization of compounds composed of many phenolic groups, hence the name poly-phenol. These compounds are plant metabolites produced as a defense against insects and other animals and are the most abundant compounds in tea comprising as much as 30-40% of both freshly plucked tea leaves and solids in tea liquor[1]. They are derived from amino acids via sunlight and therefore tea grown in the shade has a smaller concentration of polyphenols and a higher concentration of amino acids[2]. The bud and first leaf have the highest concentration of polyphenols and polyphenol levels decrease in each leaf moving down the plant[3]. There are an estimated 30,000 polyphenolic compounds in tea[4], flavonoids are arguably the most important group of polyphenols in tea and are the source of the many health claims surrounding tea, and specifically tea antioxidants. Within the flavonoid group, flavanols (also known as flavan-3-ols) are the most prevalent. Flavanols are also referred to as tannins, and during oxidation are converted to theaflavins and thearubigins—the compounds responsible for the dark color and robust flavors notably present in black teas. The major flavanols in tea are: catechin (C), epicatechin (EC), epicatechin gallate (ECG), gallocatechin (GC), epigallocatechin (EGC), and epigallocatechin gallate (EGCG). EGCG is the most active of these catechins and is often the subject of studies regarding tea antioxidants. Tea flavanols are sometimes collectively referred to as catechins. Besides flavanols, tea flavonoids also include flavonols, flavones, isoflavones, and anthocyanins; all of which contribute to the color of a tea’s infusion and its taste.

Amino Acids

Amino acids give tea its brothiness, or umami taste. Tea leaves contain many amino acids, the most abundant of which is theanine. Camellia sinensis, a mushroom called Boletus badius, and an plant called guayusa (which is often processed made into a tisane) are the only three natural sources of theanine found thus far in nature. In the tea field, sunlight converts amino acids to polyphenols, and as such; shade grown tea contains more amino acids than tea grown in direct sunlight. Some tea bushes are even deliberately shaded for several weeks before harvest to enhance the tea’s amino acid content. Theanine, more specifically L-Theanine is responsible for promoting alpha brain wave activity which promotes relaxation. L-Theanine in concert with caffeine can induce a state of “mindful alterness” in the tea drinker. In steeped tea, amino acids make up 6% of the extract solids[1].

Enzymes

Polyphenol oxidase and peroxidase are the most important enzymes in tea leaves. They are

responsible for the enzymatic browning of tea leaves that takes place when the cell walls in the leaves are broken and the polyphenols are exposed to oxygen – otherwise known as oxidation. These enzymes may be denatured or deactivated using heat so that browning cannot occur; this is one of the first steps in green tea production and is why finished green tea leaves remain green. The enzymes may also be denatured by simply depriving them of moisture for a time which is what happens during the long withering period in white tea production.

Pigments

Plant pigments are responsible for absorbing light for photosynthesis. Pigments also give leaves their color. There are two major groups of pigments in fresh tea leaves: chlorophylls and carotenoids. These pigments condense during withering and oxidation and become darker. During oxidation, the green color of tea chlorophylls is converted to black pigments known as pheophytins. This conversion leads to the dark appearance of finished oxidized teas. Tea carotenoids are another pigment group found in tea leaves and are mainly composed of carotenes which are orange and xanthophylls which are yellow and are also responsible for the color of finished tea leaves.

Carbohydrates

All plants store energy formed during photosynthesis in starches and sugars, otherwise known as carbohydrates. Plants later use this stored energy to fuel important reactions, in tea, carbohydrates help to fuel the enzymatic reactions that take place during oxidation and are also responsible for the creation of polyphenols in young tea leaves. Carbohydrates make up on average 11% of extract solids in steeped tea[1] and lend to its sweetness.

Methylxanthines

Methylxanthines in tea include the stimulant caffeine and two similar compounds: theobromine and theophylline. The tea plant creates these chemicals as a natural combatant towards insects and other animals. On average, methylxanthines in tea leaves make up 2% to 5% of the dry weight of the fresh leaves[5]. Methylxanthines also contribute to a bitter taste in the tea infusion. Levels of these compounds depend on the variety and cultivar of Camellia sinensis used, climate, age of the leaves, and the propagation method (seed vs. cutting) used on the plant.

Minerals

28 mineral elements have been found in the tea flush[5]. Compared to other plants, tea has a higher than average amount of: fluorine, manganese, arsenic, nickel, selenium, iodine, aluminum, and potassium[5]. Tea also has an unusually high amount of fluorine, which has been known to help prevent tooth decay in humans, however too much fluorine can be harmful. It is important to note that fluorine occurs in greater amounts in older tea leaves. Tea minerals vary greatly with each harvest and change greatly during processing.

Volatiles

The volatile substances in tea leaves are largely responsible for a tea's flavor and aroma. The aroma complex of tea is made up of hundreds (maybe even thousands) of flavor and aroma compounds that exist in trace amounts. Many of these aromatic compounds do not exist in fresh tea leaves and are derived from other substances during processing. The flavor and aroma of each tea depends on a wide variety of combinations of these compounds, hence the name aroma complex. Compounds such as, linalool and linalool oxide are responsible for sweetness; geraniol and phenylacetaldehyde are responsible for floral aromas; nerolidol, benzaldehyde, methyl salicylate, and phenyl ethanol are responsible for fruity flavors; and trans-2-hexenal, n-hexanal, cis-3-hexenol, and b-ionone are responsible for a tea's fresh flavor[6]. When studying tea's aroma complex, it is sometimes broken into two parts: primary aroma (from fresh tea leaves) and secondary aroma (products of manufacture). Regardless, more and more research is being done on tea volatiles and how our olfaction system works in general, so we may expect some clarity on this issue in the coming years.

Tony Gebely, 2015Tea Education, www.worldoftea.org/tea-chemistry/

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