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Effect of Water Hardness and Free Residual Chlorine on Black Tea Brew

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***Abstract*—**Water used for brewing tea plays a major role in the quality of tea. Water with higher hardness gives very dark coloured brew. This study was conducted to determine the effect of water hardness and free residual chlorine on the quality of black tea liquor. Theaflavin (TF) and Thearubigin (TR) levels are lower in comparison with the tea brewed in distilled water. At the same time, there is an increase in High Polymerized Substance (HPS) and Total Liquor Colour (TLC). While water with higher hardness has a negative impact on tea brew, water with high concentration of free residual chlorine did not affect the quality of tea brew.

***Keywords*—**Theaflavin, Thearubigin, high polymerized substance, total liquor colour, hardness, residual chlorine.

I. Introduction

TEA is one of most popular beverages in the world. Tea requires less hardness of water for brewing, i.e. less than 60 ppm [1]. If the water quality is good, the resulting brewed tea is also good liquor because a brewed cup of tea is mostly water. The quality of the water is as important as the quality of the tea leaf. The water must be free of contaminants and minerals and it should contain enough oxygen to enhance the natural tea [2]. Moreover, there are a number of additional factors that affect the taste of infusion. When hard water is used for brewing tea, filtration is required. Bleaching powder (calcium hypochlorite) used to kill bacteria in water is combined with mineral and chemical deposits which can significantly affect the taste, the liquor, and the tea drinker's overall health. The brewer should remove chlorine and other chemicals as well as the sediment from water [3]. Chlorinated tap water destroys the flavour of tea also. Water described as "hard" is high in dissolved minerals, specifically calcium and magnesium. These minerals accumulate in water and adversely affect the taste and clarity of tea. Tea brewed with pure water (distilled water) containing no minerals produces a crisp flavor and a clear brew that is aesthetically agreeable [4]. Hard water can also affect the appearance of tea by making it dark and murky. Hard water often results in an undesirable taste and also reduces the aesthetic portion of the tea by bleaching the color of the leaves. Water with high mineral content (bottled) has the same negative impact on tea liquor [5]. This study gives in detail about the influence of water hardness and free residual chlorine on quality of tea brew.

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II. Materials and Methods

A. Tea

Fanning's grade black tea used in this study was manufactured from UPASI Tea Research Foundation mini factory, Glysdale farm, Coonoor, The Nilgiris, Tamilnadu, India.

B. Tea Brewing Water

Water with different hardness levels (well water - Coonoor, river water - Rasipuram, ground water - Murarbadu), distilled water, and filter water (Aqua tech) were used in this study. The hardness of the different waters was determined.

C. Free Residual Chlorine

Water with different chlorine concentration (calcium hypochlorite from Merck in distilled water) was used in the study (0.5, 1.0, 3.0, 5.0, and 10.0 ppm). The concentrations were confirmed by iodometric titration.

D. Tea Brew

2 g tea was weighed in 250 ml conical flask; 100 ml freshly boiled water was added and kept in water bath (Temperature above 85 °C) and steeped for 10 min. After 10 min, steeped tea was filtered by using cotton [8]. The brewed tea liquor was analysed for its TF, TR, HPS, TLC, pH, and EC.

E. Chemicals

Isobutyl methyl ketone (IBMK), butanol, disodium hydrogen phosphate, calcium hypochlorite, and all other chemicals and solvents of high analytical grade (Merck) were used.

F. Analysis

Analysis was carried in UPASI Tea Research Foundation, Regional centre, Coonoor, The Nilgiris, Tamilnadu, India, a NABL (National Accreditation Board for Testing and Calibration Laboratories) accredited laboratory for chemical testing as per ISO/IEC 17025:2005. All analytical results were calculated on dry matter basis (DMC).

G. Determination of pH and EC

The brewed tea pH and EC was measured with an electronic pH meter (Mettler Toledo- Seven Easy) and conductivity meter (Systronics 304) at 25 °C.

H. Determination of TF, TR, HPS and TLC

25 ml of tea brew was extracted with 25 ml of IBMK at room temperature. After phase separation, 1 ml of upper IBMK phase was mixed with 9 ml of 45% ethanol, and

absorbance was measured at 380 nm (A) and the aqueous phase retained for TR estimation. 10 ml of IBMK phase was extracted with 10 ml of 2.5% disodium hydrogen phosphate. After extraction and phase separation, 1 ml of IBMK phase was mixed with 9 ml of 45% ethanol, and absorbance was measured at 380 nm (C). 10 ml of aqueous phase from the first step was extracted with 10 ml of n-butanol. After phase separation, 1 ml of n-butanol layer was mixed with 9 ml of 45% ethanol, and absorbance was measured at 380 nm (B). 1 ml of second step aqueous phase was mixed with 9 ml of 45% ethanol, and absorbance measured at 380 nm (D). 1 ml of tea brew was mixed with 9 ml of distilled water and absorbance measured at 460 nm (E). The absorbance was measured in UV Spectrophotometer (GBC 913, Australia) [6]. Concentration of TF, TR, HPS and TLC was calculated from the absorbance values as given below. The calculation factors include molar extension coefficient and dilution [7], [8].

$$TF\% = C*4.313$$

$$TR\% = (A+B)-C*13.643$$

$$HPS\% = D*13.643$$

$$TLC = E*10$$

III. Results and Discussion

A. Hardness Impact

Distilled water with zero hardness was taken as reference. The quality of tea liquor brewed with distilled water was compared with different tea liquors brewed in water with different hardnesses. Ground water with the high hardness gave poor quality tea brew; i.e., ground water had very high hardness (Table I). In the ground water brewed tea, the TF levels were almost reduced by 50%. The TF levels were low in brew steeped in hard water (Table II). A low TF level gives negative impact on tea brew [9]. TR was reduced by more than 20% and polymerisation increased to almost 40% as compared to distilled water. The liquor colour is also intensified but the colour developed was due to high polymerised substances and it gave very dark cloudy appearance which is undesirable. Highly dark coloured tea brew does not appeal to drinkers [10]. Electrical conductivity (EC) of ground water was high, which is due to the high amount of minerals present in the water. Water with high mineral content causes scum in tea brews [11]. These minerals react with the tea polyphenolic compounds to produce scum and very dark coloured brew. The above results show that the pH of tea brewed in ground water drastically varied from that of tea brewed in distilled water. The pH of distilled water is slight acidic and that of ground water is neutral.

The pH level of the tea brewed from distilled water reduces to its original level, i.e. 5.75 to 4.80 (Table II), whereas the pH reduced when tea was brewed by using ground water and this is due to high mineral content which gave buffering capacity to water.

TABLE I
Quality Parameters of Water Collected from Different Source

Water source	pH	EC (dS/m)	Total Hardness as $CaCO_3$ (mg/L)	Ca as $CaCO_3$ (mg/L)	Mg as $CaCO_3$ (mg/L)
Distilled water	5.75	0.00	Nil	Nil	Nil
Filter water	7.00	0.05	22	8	14
Well water	5.95	0.06	22	8	14
River water	7.90	0.36	135	105	30
Ground water	7.30	2.20	701	350	350

TABLE II
Liquor Quality of Tea Brewed from Different Water Source

Water source	TF %	TR %	HPS %	TLC	pH*	EC (dS/m)*
Distilled water	0.81	8.38	9.58	3.96	4.80	1.10
Filter water	0.74	8.33	9.67	3.68	4.80	1.15
Well water	0.78	8.55	9.99	4.08	4.80	1.17
River water	0.59	7.37	11.94	4.27	5.45	1.24
Ground water	0.44	6.37	13.21	5.32	6.20	2.90

*: 2% Brewed tea.

The tea brewed from river water was compared with tea brewed from distilled water. Tea brewed from distilled water gave better results than tea brewed from ground water as distilled water contained no minerals. The pH of river water was higher than all other waters because of purification techniques (bleaching powder - calcium hypochlorite) used by municipality officials. The hardness was lower than ground water, and the TF reduced by almost 25%, TR reduced by 15%, and the polymerization increased by 20% as compared to distilled water. The tea liquor colour also increased by 10% due to the hardness and high pH. Quality deterioration is mainly due to high pH of water. Hardness of river water was 135 ppm which is the normal level (Table I). The river water brewed tea has low pH of 5.45 and it is comparable with distilled water. This drastic reduction of pH was because of low mineral content and low buffering capacity. Here, river water gives higher quality tea liquor than ground water. Well water and purified water have almost same quality except for pH levels. The quality of tea brew was determined by the pH of tea brewing water [12]. pH of filter water was neutral due to filtration technique (Carbon and RO filtration) in the filter. Both hardness and EC were same in well water and purifier water but TF slightly reduced in the tea brewed in purifier water due to high pH. The pH of well water was nearly equal to distilled water. Hence, tea liquor quality was better than all other waters. TF, TR, HPS, TLC and pH of well water was almost same as distilled water. There was a slight variation in EC due to the presence of minerals. The low EC soft water has no negative impact on tea brew [13]. However, these minerals did not affect the tea liquor quality.

B. Free Residual Chlorine (FRC) Impact

The tea liquor brewed from distilled water was taken as reference and compared with different concentrations of chlorine. The chlorine concentration did not affect the liquor quality up to 3.0 ppm. Above 3.0 ppm there was a decrease in the quality at concentration of 5.0 and 10.0 ppm (Table III). Water with higher concentration of chlorine mainly affected

the TF because chlorine has oxidation property [3]. Hence, the excess chlorine directly reacts with TF and reduced the TF level [9].

The lower concentration of Cl_2 did not affect the quality parameters and slightly increased the EC. This EC value was due to the addition of chlorine from calcium hypochlorite for preparation of chlorinated water. Increase in pH and EC value of tea liquor with higher chlorine was due to mineral content. The quality of tea brew was not affected.

TABLE III
LIQUOR QUALITY OF TEA BREWED FROM DIFFERENT CONCENTRATION OF FREE RESIDUAL CHLORINE WATER

Concentration Cl2 ppm	TF %	TR %	HPS %	TLC	pH*	EC (dS/m)*
0 (Distilled water)	0.85	8.87	8.38	2.97	4.88	1.08
0.5	0.81	9.12	8.41	2.90	4.87	1.10
1.0	0.80	9.00	8.32	2.97	4.87	1.10
3.0	0.88	8.88	8.27	2.90	4.88	1.13
5.0	0.75	9.02	8.26	2.84	4.92	1.15
10.0	0.73	8.93	8.45	2.90	4.96	1.15

*: 2% Brewed tea.

IV. CONCLUSION

It is clear from the above study that the hardness of water mainly affects the quality of tea brew. Soft, neutral, or slight acidic water should be used for brewing. Tea brewed with soft water retains quality, but hard water containing minerals reacts with tea polyphenolic compounds to give inferior liquor. Most of the polyphenolic compounds are stable only in acidic condition.

The free chlorine can be a source of carcinogenic diseases. 0.2 ppm is the permissible limit of free chlorine as per Indian standard [14]. Purification of water using calcium hypochlorite may increase the FRC. Above the permissible limit, FRC does not affect the brewing quality as FRC escapes from water when boiling. The quality of tea brew is not determined by the desired tea, but also by the water used for brewing. Bad quality water gives bad tea with inferior liquor which has undesirable qualities. Good quality water gives good tea with appeal and taste.

Fig. 1 Tea brewed Soft and Hard water

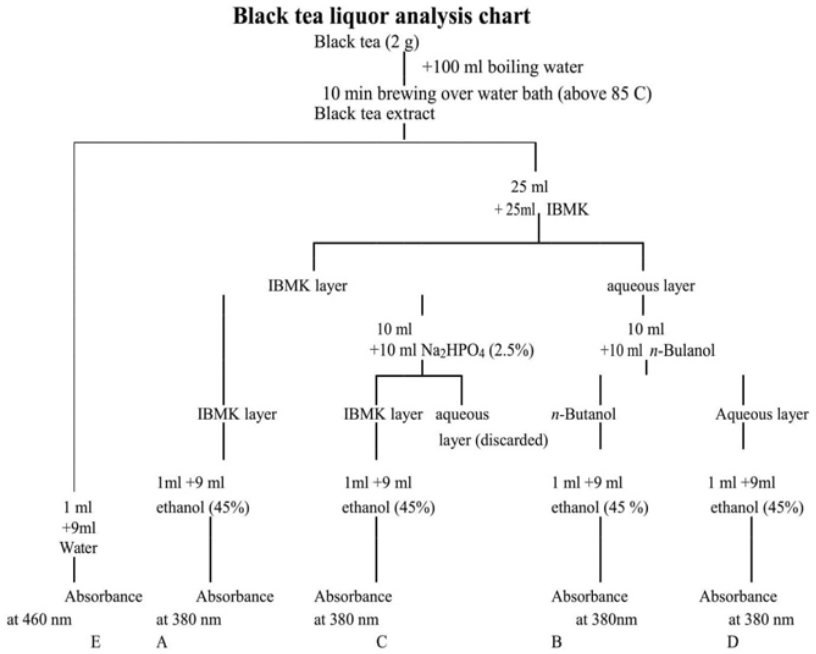

Fig. 2 Black tea liquor analysis chart

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