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Research Article

Impact of temperature and fermentation period on the overall quality of black tea

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Abstract

Black tea processing fermentation was studied at different temperatures and times. Time and temperature have a significant effect on the aflavin content of black tea. Highest mean percentage of the aflavin (0.53%) was recorded at 20-210C while the lowest percentage (0.41%) was seen at 28-29 0C. Significant effect was also found on the the arubigens where maximum mean value (17.36%) was found at 180 minutes and minimum (15.97%) at 100 minute. Time and temperature have a significant effect on TSS. Maximum mean value (36.47%) was recorded at 120 minutes and minimum (33.90%) at 180 minute. On caffeine and acidity, there was no significant effect of time and temperature. However, the significant effect was found on quality, hue and thickness. For quality, maximum mean score (4.52) was noticed at 100 minute and minimum (4.22) at 180 minute at 20-21 0C highest mean score (4.57) and the lowest score (4.28) at 28-29 0C was observed. Maximum and minimum mean hue score was (4.43) and (4.06) at 120 minutes and 100 minutes respectively. While at 28-29 0C highest mean scores (4.53) and lowest, score (3.99) at 24-25 0C was recorded. Maximum mean score (3.94) and minimum (3.78) were found in thickness at 120 minutes and 180 minute respectively. At 20-21 0C high mean scores of (3.93) and a low score of (3.76) at 28-29 0C was observed.

Keywords: Temperature; Fermentation period; Quality; Black tea; Total Soluble Solid; Acidity

Introduction

Black Tea, botanical name is *Camellia sinensis. L.* belongs to family the aceae, and is a perennial herbaceous and dicotyledonous crop **[1]**. In ancient China tea was originally known for its medicinal properties **[2]**. The medicinal use of tea is recorded in medical book of the Tang Dynasty (618-609 AD) where it was noted that it has disease curing and detoxicating activity (Chen) with the expansion of tea cultivation and development of the processing technique, tea became a popular beverage in China and was considered a symbol of social status and civilization. Gradually the practice of tea drinking spread

throughout the world [3, 2]. The origin of tea is China and its regular drinking began there in 16th century A.D [4, 5]. It spread to Japan in 1000 AD and by the middle of the 17th century; black tea has become popular in Europe. In the middle of 18th century, British started black tea cultivation in India and other colonies [6, 7]. The Indians (South East, Sub-Continent) got familiar to tea due to British rule in 18th century [8]. The main tea producing countries are India, China, Srilanka, Indonesia, Turkey, Japan, Vietnam, Bangladesh, and Argentina whereas exporting countries are Srilanka, Kenya, China, India, Indonesia, Vietnam, Argentina, Malawi, Uganda and Tanzania [2, 9, 6]. Major tea importing countries is Russia, UK, Pakistan, USA, Egypt, Japan, Iraq, Morocco, Iran and Poland [8, 10].

Tea is a traditional beverage of Pakistan and per capita consumption is 1kg per annum. Pakistan imports its entire black tea requirement "from abroad and thus, the total annual import of black tea was 2, 60000 m tons in 2000 worth Rs.12 billion [11-13]. Presently Pakistan is the 2nd largest importer of black tea. Demand for black tea is growing day by day and in the wake of high growth rate of population (3.1% annually); Pakistan is likely to become the world largest importer of black tea by the year 2010" [1, 4, 11]. Although the climatic conditions of Pakistan are not 100% fit for tea cultivation yet the prospective teas growing areas in Pakistan are located in Hazara and Swat in Khyber Pukhtunkhwa lying around 34.8219^{o} N latitude and 72.1854^{o} E longitude in a contiguous belt in the foot hills of Himalayas and Hindukush [11]. The period from December to March is coldest with air temperature ranging from 0.12 ^{o}C causing the arrest of vegetative growth of the plants. With the onset of spring, the growth starts in April and continued through the summer till autumn.

Tea cultivation started for the first time in Pakistan in 1958 at village Baffa (Distt. Mansehra) under the auspices of Pakistan Tea Board. The 2nd attempt was made in 1964 and a pilot project "Irrigated Tea Plantation" was initiated by the West Pakistan Agricultural Development Corporation at Misriot Dam near Rawalpindi. The National Tea research institute was established in 1984 at Shinkiari, District Mansehra under Pakistan Agricultural Research Council Islamabad. Chinese experts visited the prospective tea growing areas in 1988 and submitted a comprehensive report on the economic feasibility of tea cultivation in Pakistan [11]. Unilever Pakistan Limited (UPL) on its own started a parallel exercise in 1987. Unilever concluded after research that although conditions for black tea growing in Pakistan are not ideal yet tea can be grown in Hazara and swat region. In 1989, Unilever established a small and well equipped tea research station on 9 acres of land at Shinkiari in Mansehra. After ten years of research, Unilever established first modern CTC (Cut, Tear, Curl) tea processing plant in Pakistan near Dhodial (Mansehra) in 2001 inaugurated by the President of Pakistan General Pervez Musharraf. In Pakistan tea has been cultivated in Distt. Mansehra, Battagram and Abbottabad mostly by Unilever Pakistan limited spending millions of rupees with attractive incentives to farmer's i.e. young tea plants are provided to the farmers free of cost along with free fertilizers, acidifying chemicals and expertise [4, 10, 13].

National tea research institute Shinkiari (Mansehra) under PARC (Pakistan Agricultural Research Council) has also planted tea on a small area in Distt. Mansehra, Battagram and Swat. Processing Plant has been established with the help of China on NTRI, Shinkiari Mansehra.

Tea plant requires all those factors, which are essential for other plants growth. The climate, soil structure and pH are the important factors responsible for its growth. Ta requires 1000-1500mm evenly distributed rainfall annually and air temperature, ranging from 20^{o}C -30^{o}C for optimum growth. Well drained plain and sloppy lands can be successfully exploited for tea cultivation. Tea is cultivated in a sandy loam soil and requires acidic soil having pH 4.5 to 5.5 **[1, 5, 8]**. The flavor and quality vary with the soil, climate and age of the leaf, time of plucking and method of preparation **[3]**. The international standard for plucking is two leaves and a bud but in Pakistan due to marginal condition we take three leaves and a bud. Soluble solids measurement is a good indicator of the potential mouth feel and thickness of black tea liquor **[1]**.

Research conducted on tea for its medicinal value shows that it contains stress fighting vitamin C, antioxidant vitamin E a disease fighting vitamin A it contains catching a chemical compound, said to kill bacteria and viruses **[4, 5]**. It acts as a blood thinner and inhibits blood platelets clumping together, a major factor in depositing cholesterol in blood vessels **[14, 15]**. Tea is good for diabetes as it contains polyphenols, which help in preventing too much sugar from absorbing in the blood pressure. Tea prevents colon cancer in particular and may shrink existing cancers and stop them from spreading to other parts of the body **[3]**. Tea as a beverage either black or green is considered as a traditional beverage in Pakistan and particularly in Khyber Pukhtunkhwa. This study was designed to find out how the fermentation time and temperature influences the chemical composition and organoleptic characteristics of black tea. The study will be helpful for tea processors and ultimately to the end users.

Methods and materials

The present research work was carried out in Unilever tea processing plant Dhodial. Black tea is manufactured from fresh leaves. Leaves were taken from tea gardens and brought in the tea processing unit on the factory. After withering, crushing the leaves were cut, tea red and curled in 4 sets of Cut-Tear-Curl (CTC) machine to get the desired size. Fermentation was carried out by enzyme polyphenols oxidize; the leaves were dried in fluid bed drier to reduce the moisture content. After grading and sorting of tea particles the made tea was packed in aluminum coated sacks.

Results

The aflavin

The aflavin is considered to be the responsible for color developed during fermentation. Results regarding the aflavin content are presented in Figure 1. The highest the aflavin was noticed on 20-21°C at 180 minutes of fermentation time. While the minimum value of the aflavin 0.35% was noticed for 180 minutes at 28 - 29°C temperatures. Statistical analysis revealed that both time and temperature have a significant influence ($P< 0.01$) on the aflavin content of black tea. The maximum mean value is 0.48% was recorded for 180 minutes of fermentation time followed by 0.47% at 100 and 160 minutes respectively. While the minimum value of 0.46% was observed at 28-29°C. The highest percentage of the aflavin 0.53 was recorded at 20 - 21°C followed by 0.47 at 24 - 25°C, while the minimum value 0.41% was observed at 28-29°C. The interaction of fermentation time and temperature has significant effect on the aflavin content. From these findings it is indicated that increasing the fermentation temperature lowering the the aflavin content.

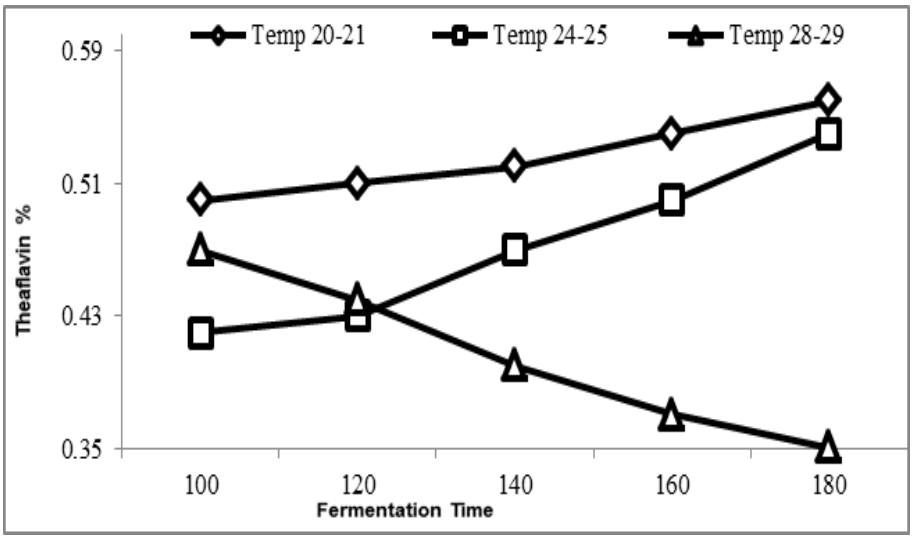

Figure 1. Influence of fermentation temperature and duration on theaflavin Content in black tea

The arubigens

Reddish brown the arubigens are responsible for the color of made tea. The arubigens are formed during the fermentation process, which largely depends upon fermentation time and temperature. The influence of fermentation time and temperature is presented in Figure 2. The maximum percentage of the arubigens was observed 17.45% on 180 minutes at 24-25°C while the minimum value of 15.53% was noticed on 100 minutes of fermentation at 28- 29 C. Statistical analysis showed that maximum mean value was 17.36% at 180 minutes followed by 16.28%, 16.44%, 16.64% at 120, 140 and 160 minutes respectively, while the minimum value was recorded 15.97% at 100 minutes. The highest mean value was observed 17.01% at 24 - 25°C followed by 16.35% at 20-21°C and the lowest value was recorded 16.25% at 28 - 29°C. The interaction between fermentation time and temperature was found non-significant with respect to the arubigens contents. From these results, it is indicated that by increasing fermentation temperature lowering the the arubigens content.

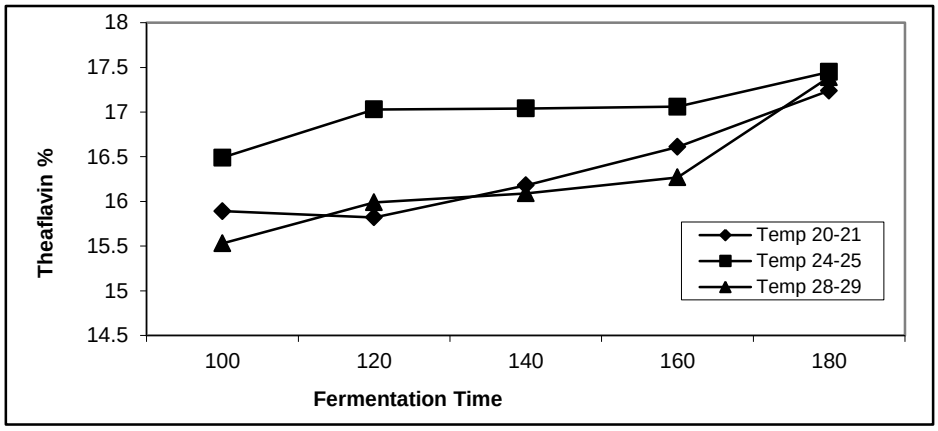

Figure 2. Influence of fermentation temperature and duration on Thearubigens content in black tea

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Total soluble solids

Thickness is an important attribute of black tea and depends upon amount of TSS present. TSS include TF, TR. Increase in these contents with an increase in TSS then more will be its thickness and better will be the mouth feel. Results regarding TSS content are presented in Figure 3. The amount of TSS was determined at different time and temperature to get good quality black tea. The highest value of TSS 38.72% was recorded on 120 minutes at 20-21°C while the minimum value of 32.93% was observed on 160 minutes at 28-29°C. Statistical analysis revealed that both fermentation time and temperature have a significant influence ($P<0.01$) on TSS content of black tea. The Maximum mean value was 36.47% and 36.07% at 120 and 100 minutes of fermentation followed by 35.86% and 35.11% at 140 and 160 minutes respectively. The highest mean value of TSS was recorded 37.45% at 20 - 21°C followed by 34.79 at 28-29°C and lowest value 34.20 was observed at 24 - 25°C. From the result it is clear that the interaction between fermentation period and temperature have significant effect.

Caffeine contributes briskness of black tea. The extent of cream formation is largely dependent on the amount of caffeine present in tea. It is colorless and contributed to pungency moderate intake of caffeine is beneficial for good functioning of nerves system. The influence of fermentation time and temperature on caffeine contents is presented in Figure 4. Maximum value of caffeine 2.35% was recorded at 140 minutes at 28 -29°C. While the lowest value of 2.31% was noticed about 100, 140, 160 minutes at 24 -25°C temperature. Statistical analysis revealed that both time and temperature have a non- significant influence on caffeine contents of black tea. The maximum mean value is 2.32% was recorded at 100 to 120 and 140 minutes. While the lowest mean value was recorded 2.31% on 160 and 180 minutes. The highest mean value 2.32 was recorded at 20-21°C and 28 - 29°C and the lowest was observed 2.31 at 24 -25°C. The result showed that the interaction between fermentation period and temperature has non-significant effect on caffeine contents.

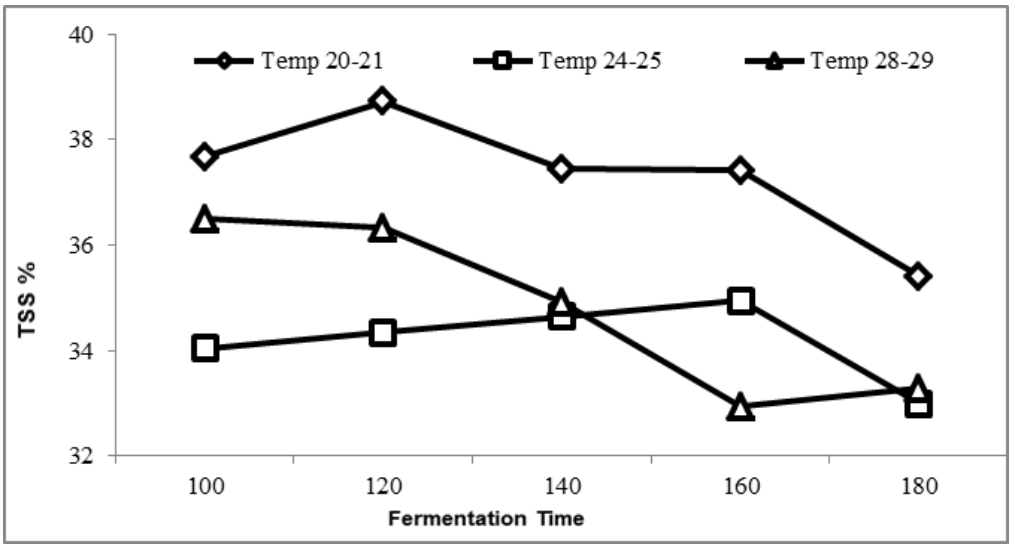

Figure 3. Influence of fermentation temperature and duration on TSS content in black tea Caffeine

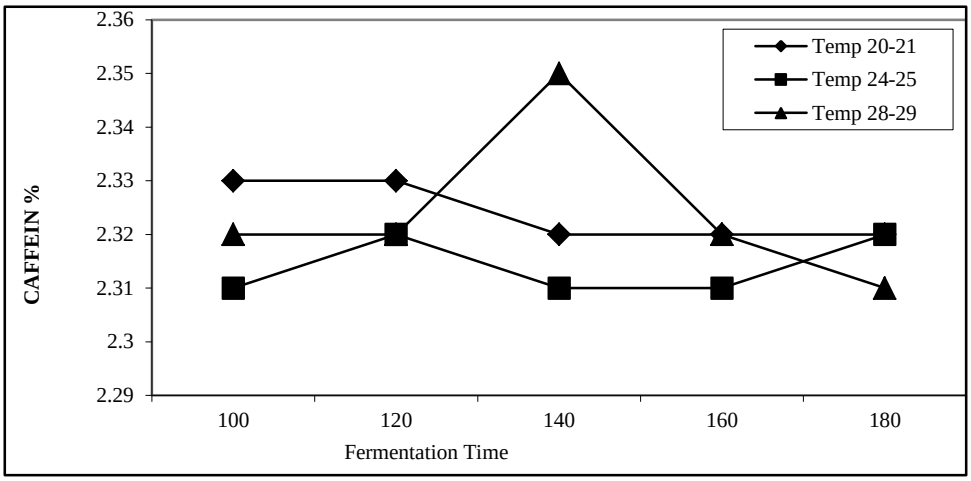

Figure 4. Influence of fermentation temperature and duration on Caffeine content in black tea

Acidity

Acid is the by-product of any fermentation process in tea, during this process linolenic, aldehyde are formed due to which tea is acidic in nature. Results regarding acidity content are presented in Figure 5. The maximum value of 5.43% was noticed in 160 minutes at 24 -25°C. While the lowest value of 5.28% was observed at 180 minutes at 28 -29°C temperatures. Statistical analysis showed that both time and temperature have a non-significant effect on acidity of black tea**.** Maximum mean value was 5.38% at 160 minutes followed by 5.36% and 5.35% at 100 and 180 minutes of fermentation, while the minimum value of 5.34% was recorded at 120 and 140 minutes. The highest mean value is 5.36% was recorded at 24 -25°C and 28 -29°C followed by 5.35% at 20 - 21°C. The result shows significant effect on acidity between fermentation period and temperature.

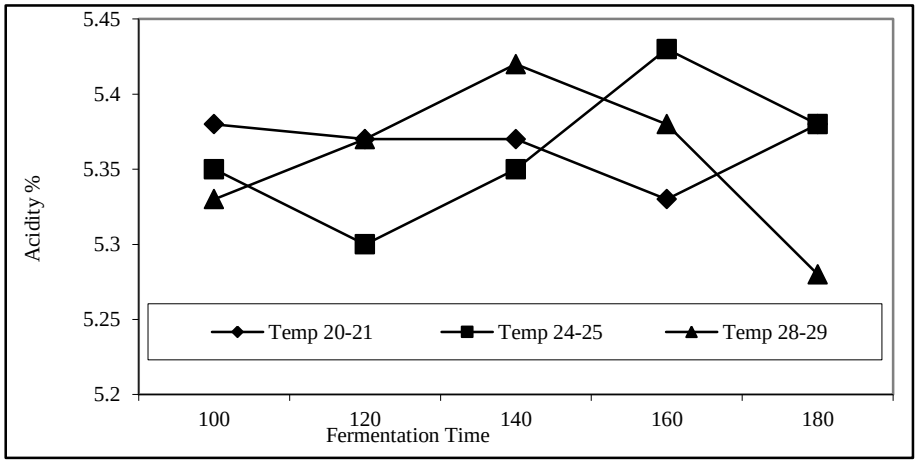

Figure 5. Influence of fermentation temperature and duration on Acidity

Quality

Quality shows the mouth feel and taste of black tea. Quality largely depends upon the presence of TF, TR and caffeine. With the increase of these contents, good quality of black tea will be processed. Quality of black tea is dependent on chemical components formed during the processing stage. These

chemical components contribute liquor, color, brightness and taste of black tea. Physical and chemical withering also influences the taste and quality of black tea. The influence of fermentation time and temperature is shown in Figure 6. Results of the effect of different fermentation time and temperature on quality of black tea showed that the maximum mean value, 4.63 was recorded on 100 minutes at 20 - 21°C while the minimum value, 4.00 was observed at 180 minutes, at 24 -25°C. Statistical analysis revealed that both time and temperature have a significant influence (P<0.01) on quality of black tea. Maximum mean value was 4.52% at 100 minutes while minimum of 4.39% was recorded at 140 minutes. The highest mean value, 4.57 was recorded at 20 - 21°C followed by 4.34% at 24-25°C and the lowest was 4.28% observed at 28-290C. They have a significant effect on quality due to the interaction between fermentation time and temperature.

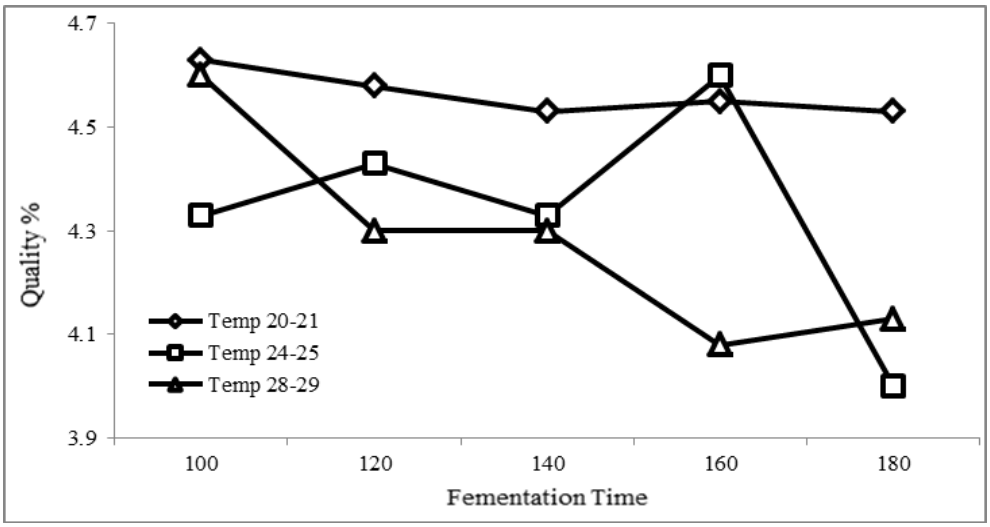

Figure 6. Influence of fermentation temperature and duration on Quality

Hue

Hue means color and as TF. TR are responsible for color thus, hue will be dependent on their presence. Results regarding TSS content are diagrammatically shown in Figure 7. Result pertaining to the influence of different fermentation times and temperature on hue of black tea. Highest value of 4.63% was noticed in 120 minutes at 20-21°C. While the lowest of 3.77% was recorded at 160 minutes at 24-25°C temperature. The analysis of variance revealed that both time and temperature have a significant influence (P<0.01) on hue content of black tea. Maximum mean value is 4.43% in 120 minutes followed by 4.06%, 4.14%, 4.22% at 100, 140 and 180 minutes respectively while the lowest was 4.08%, recorded at 160 minutes. The maximum mean percentage, 4.35% was observed at 28 - 29°C while the lowest hue value was recorded, 3.99% at 24 -25°C.

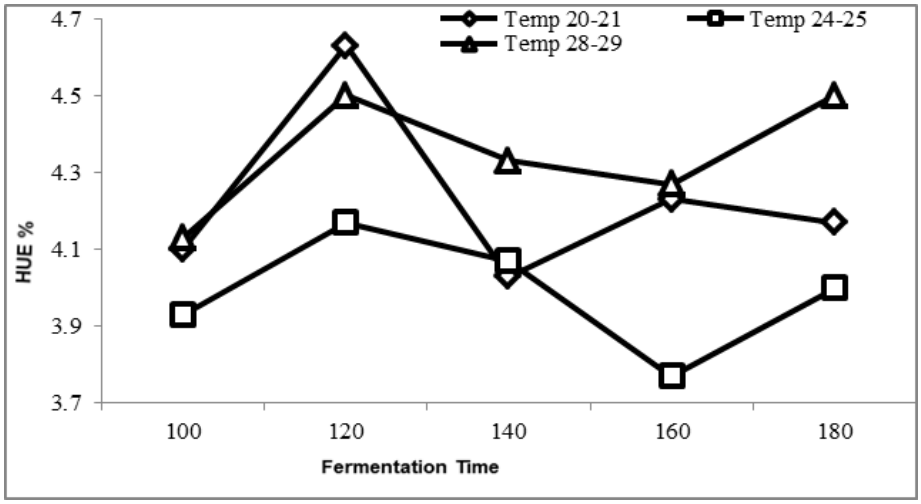

Figure 7. Influence of fermentation temperature and duration on Hue

Thickness

Thickness depends upon TSS, TF, TR and caffeine. The influence of fermentation time and temperature is presented in Figure 8. The maximum value 4.13% was observed at 120 minutes at 20-21°C. While the minimum value 3.60% at 28 - 29°C was recorded at 180 minutes of fermentation. The analysis of variance revealed that both time and temperature have significant influence on thickness of black tea**.** The maximum mean value is 3.94% was recorded at 120 minutes followed by 3.83%, 3.84% at 100 and 140 minutes while the minimum value 3.78% was observed at 180 minutes of fermentation. The highest mean value of 3.93% was recorded at 20 - 21°C followed by 3.85% at 24 - 25°C and lowest value was 3.76% was found at 28 - 29°C.

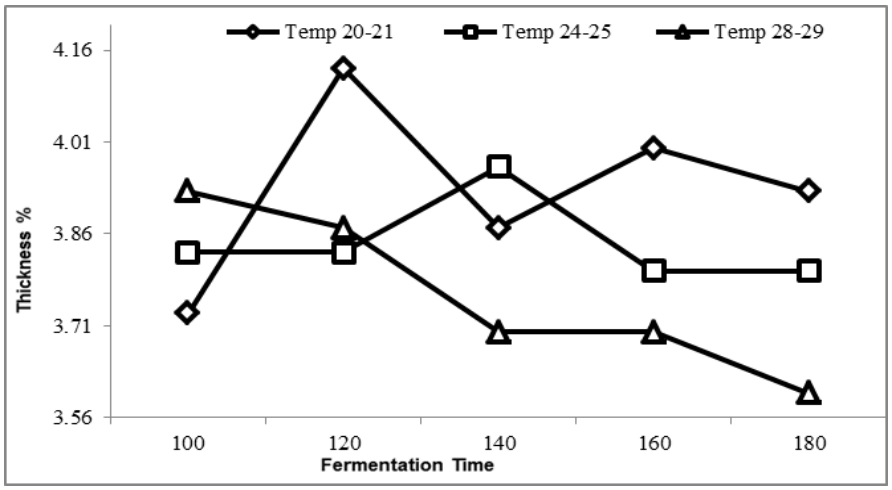

Figure 8. Influence of fermentation temperature and duration on Thickness

Discussions

Tea (*C. sinensis*) plants grown at In Tea Research garden were obtained to process the tea at various fermentation temperature and period. In the process of producing international standard tea, it has been recognized that there should be some chemical constituents whose presence in certain amounts ensure the quality of black tea. These constituents are the aflavin, the

arubigens, TSS and caffeine. The influence of fermentation temperature and period on these constituents is presented in Figure 1-8. From these findings, it is indicated that increasing the fermentation temperature lowering the the aflavin content. These findings are in close contest of **[14-16]** that carried out research work on fermentation temperature and found that the low fermentation temperature improves black tea quality increasing fermentation temperature lowering the the arubigens content. Our results are in agreement with **[12, 13, 14, 17]** that carried out research work on quality parameters and found that fermentation duration and temperature have significant influence on the quality of tea. Low fermentation temperature black tea has higher levels of the arubigens and brightness. **[17, 10, 2]** reported that processing of black tea at low fermentation temperature improved black tea quality. Long fermentation duration and low temperature favored production of more intensely colored black tea. The trend in the decrease of caffeine content is supported with the findings of **[12, 15]** showed that the caffeine content changed throughout the various stages of black tea production. The decrease in caffeine levels during fermentation was related to the time and temperature of fermentation. **[18, 19]** studied that acid is the by-product of any fermentation process in tea, during this process linolenic, aldehyde are formed due to which tea is acidic in nature. These findings are in close contest of **[16, 14]** which reported that black tea chemical quality parameters varied with fermentation temperature period.

Conclusion

Fermentation is a major and important process of tea processing in which the aflavin and the arubigens are formed. From the result, it was concluded that a proper balance between the aflavin and the arubigens which is very necessary for quality and also depends upon the duration and temperature period of fermentation. It is also concluded from the experiment that fermentation duration, 120 min and temperature range, 20 – 21^{o}C showed the best result regarding the overall quality of black tea.

Authors' contributions

Conceived, designed and performed the experiments: S Wahab, Analyzed the data: F Ullah & MS Memon, Contributed reagents/ materials/ analysis tools: MK Khattak, L Hassan, Wrote the paper: F Ullah.

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