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Quality assessment of locally produced black tea in Sardauna Local Government area of Taraba State, Nigeria

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ABSTRACT

Background**:** Tea processing is a big investment among local tea processors on the Mambilla plateau. Tea processing technique and processing facilities are important factors that determine the quality of black tea. Locally fabricated equipment is used by local tea processors due to their inability to procure multimillion naira worth of CTC machine. The current study seeks to evaluate the quality of black tea processed by the local processors.

Methods**:** Locally processed black tea samples were obtained from local tea processors on the Mambilla Plateau in Taraba State, Nigeria. Processed black tea samples were also obtained from the tea processing companies on the Mambilla Plateau. The various tea samples were analyzed for biochemical quality parameters using standard procedures.

Results**:** Proximate analysis showed that, crude protein ranged between 0.97 and 1.98%; crude fiber ranged from 19.93-25.66%; moisture content ranged from 6.76 – 10.81%; fat content ranged from 0.32 – 2.60; ash content ranged between 3.76 and 7.83%; total phenol content ranged from 90.00 – 134 mg GAE/g; caffeine ranged from2.10 – 4.16mg/100g; DPPH free radical scavenging assay ranged from 0.021- 0.079EC_{50}; theaflavin content ranged from 5.10 – 12.62mg/g while thearubigin ranged from 64.00 – 114.00mg/g.

Conclusion**:** Quality evaluation of the black tea samples showed that, the locally processed black tea was adequate in some quality parameters while there was quality deficit in moisture content, crude fibre, thearubigin and theaflavin. The processing techniques and facilities used by the local tea processors require upgrading to meet the desired quality standards.

Keywords: Black tea, fermentation, processor, Mambilla plateau, tea quality.

1.0 INTRODUCTION

Black tea is a type of tea produced from the leaves of *Camellia sinensis*. The main difference between black tea and other types of tea such as oolong, yellow, white, and green tea is the intensity of oxidation (fermentation). Though all the types of teas are made from same plant, black tea is more oxidized than the rest. The degree of oxidation imparts black tea with higher flavor, brightness of color and pleasant taste compared with other types. The uniqueness of black tea makes it incomparable with other types of tea in terms of popularity, acceptability and consumption. About 80% of global tea consumption is black tea while the remaining 20% is shared among other types of tea [1]. In Nigeria, tea cultivation is done on the Mambilla plateau in Sardauna Local Government Area of Taraba State. The cultivation of tea has been limited to the plateau for several decades mainly because the plateau is geographically located in an area that meets the soil and climatic conditions required for tea cultivation. On average, the elevation of the Mambilla Plateau is 1,600 meters above sea level with annual average rainfall of 2,845mm. The acidic nature of the soil (pH 4.60-5.60) and the low ambient temperature of 13.9-24.38^{o}C put together enhance the cultivation of tea on the plateau. More than one thousand tea farmers are involved in tea cultivation on the Mambilla Plateau. Of the known two hundred and sixteen (216) communities that exist in Sardauna Local Government Area of Taraba State, Nigeria, only thirty-three (33) communities are currently involved in tea

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cultivation. Tea farmers make income from tea cultivation when they sell the fresh leaves to tea processing companies which in turn use the leaves as raw material for the production of black tea. In recent time, several of the tea farmers have become discouraged in tea cultivation as a result of low financial returns from the sales of fresh tea leaves to commercial tea companies who in turn, process the fresh tea leaves into made tea. In attempt to circumvent the unfavorable financial earning from tea leaves sales, some of the farmers went into small scale tea processing which involves processing fresh tea leaves into black tea with locally fabricated machines. The steps were taken by the farmers after discovering that the finished products commands higher premium compared to sales of fresh tea leaves. Currently, there are forty-four (44) local tea processing machines in Sardauna LGA. This is a huge investment among local processors. Considering the socio-economic significance of local tea processing as a venture and means of livelihood on the Mambilla plateau, it became necessary to evaluate the quality parameters of the black tea being produced among the local processors with a view to comparing the quality with International standard.

2.0 MATERIALS AND METHODS

2.1: Materials

Black tea samples were collected from ten communities on the Mambilla Plateau where black tea is commercially produced. In each of the communities, selected tea processors were visited and locally processed black tea ready for market were collected. In Nyinwa community, 3 samples were obtained. Mayo-kusuku (9 samples); Nguroje (2 sample); Bangoba (3 samples); Lugere (3 samples); Kakara (3 sample); Kasalasa (3 samples); Galadima (1 sample); Kusuku (1 sample) and Maisamari (1 sample). In all, 28 subsamples were collected from each of the local tea processor. Two samples of CTC tea processed black tea were also included in the study. One sample produced by Mambila Beverage Ltd (Highland tea) and the other sample produced by Unilever (Lipton tea).

2.2 Methods

2.2.1 Physicochemical and biochemical analysis of black tea samples

Proximate analysis was carried out according to the procedure of [2]. Moisture conten of tea samples was determine by oven drying, crude protein was determined by using micro Kjeldahl method, crude fibre was determined by hydrolysis, fat content was determined by soxhlet extraction with organic solvent, ash content was determined using muffle furnace while carbohydrate was determined by weight difference. Total phenolic content will be done according to [3]. The DPPH radical scavenging activities (antioxidant activities) of the extracts will be determined according to [4]. Caffeine content in the samples will be determined according to [5]. Theaflavin, Thearubigin, Color and Brightness will be determined by the method prescribed by [6].

3.0 RESULTS

Result of the proximate analysis of the black tea samples obtained from various local tea processors and selected commercial tea is presented in Figures 1 and 2. Crude protein in the tea samples ranged from 0.97-1.98% with an average value of 1.20%. Tea sample from Mayo-kusuku 4 had the least value of crude protein while tea from Bangoba 2 had the highest value (Figure 1). The crude fiber content of the evaluated black tea samples ranged from 19.93 – 25.66% with an average value of 22.67% (Figure 2). Tea sample from Mayo-kusuku 3 had the lowest crude fiber while tea sample from Mayo-kusuku 4 had the highest value of crude fiber. The moisture content of the analysed tea samples ranged from 6.76 – 10.80% with a mean value of 9.2% (Figure 1). Tea sample code named CTC 2 had the lowest moisture content while tea sample from Mayo-kusuku 3 had the highest value of moisture. The fat content of the evaluated tea samples ranged from 0.32 – 2.60% with a mean value of 0.87%. Tea sample from Mayo-kusuku 3 had the lowest fat content while CTC 2 had the highest value (Figure 1). Ash content of the investigated black tea samples ranged from 3.76 – 7.83% with a mean value of 5.12%. Sample from Kakara 1 had the lowest level of ash while tea sample from Bangoba 1 had the highest ash content (Figure 1). Carbohydrate content of the tea samples ranged from 58.10 – 66.06% with an average value of 61.38% (Figure 2). Black tea sample from CTC 2 had the highest carbohydrate level while the processed black tea sample from Mayo-kusuku 4 had the lowest level of carbohydrate. The total phenol content of the analyzed black tea samples ranged between 90.0 and 134mg GAE/g with a mean value of 124.63mg GAE/g (Figure 3). The black tea samples of the two commercial tea brands processed with CTC machines had much lower values of polyphenols compared with the locally processed black tea. Total caffeine content of the evaluated black tea samples ranged from 2.10 – 4.16mg/100g with an average value of 3.8 mg/100g (Figure 4). Black tea sample from Lugere 2 had the least total caffeine content while one of the two commercial black tea products (CTC 2) had the highest level of total caffeine. The values obtained for the DPPH free radical scavenging assay range from 0.021 – 0.079 EC_{50} with a mean value of 0.03 EC_{50} (Figure 5). Locally processed black tea samples from Nguroje 1 and Mayo-kusuku 4 both had the lowest value of DPPH anti-oxidant capacity while tea sample from CTC 1 had the highest value of nti-oxidant capacity. Theaflavin content of the studied tea sample on the Mambilla Plateau ranged from 5.10 – 12.62mg/g with an average value of 6.11mg/g (Figure 6). Samples from Nguroge and Maissamari had the lowest value while CTC1 had the highest theaflavin content. On the other hand, thearubigin content of the samples ranged from 64.00-114.00mg/g with an average value of 71.60mg/g (Figure 7). Tea samples from Nyinwa 1, Kakara 1 and Mayo-kusuku 8 had the lowest value of thearubigins while CTC 1 had the highest value. Result showed that, the commercial tea brands CTC1 and CTC2 had significant higher content of theaflavin and thearubigins than the locally processed black tea on the Mambilla plateau.

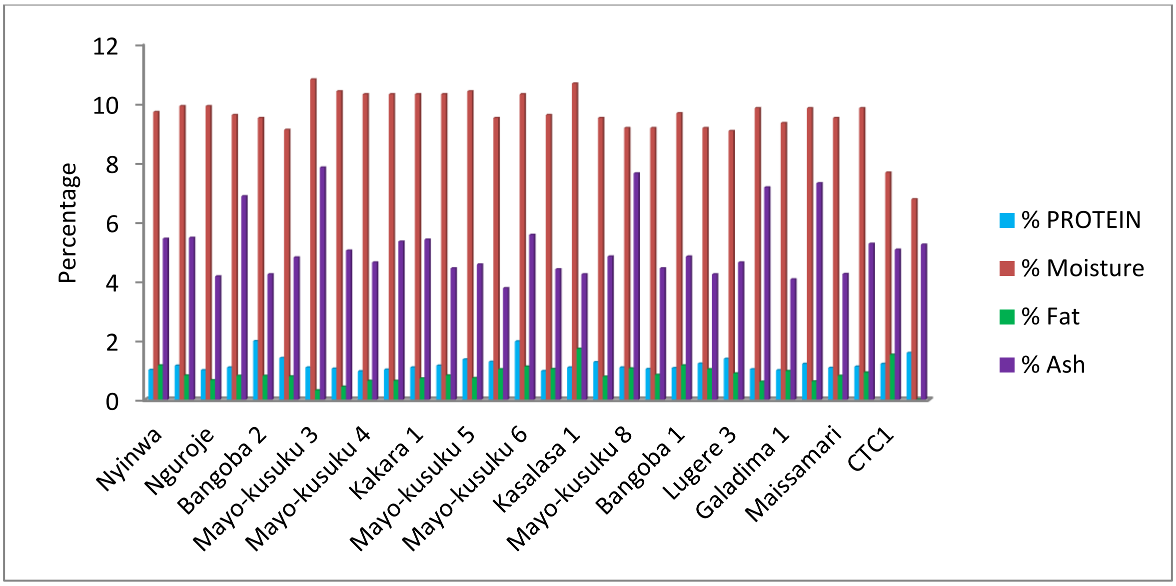

Figure 1: Protein, Moisture, Fat and ash content of black tea samples

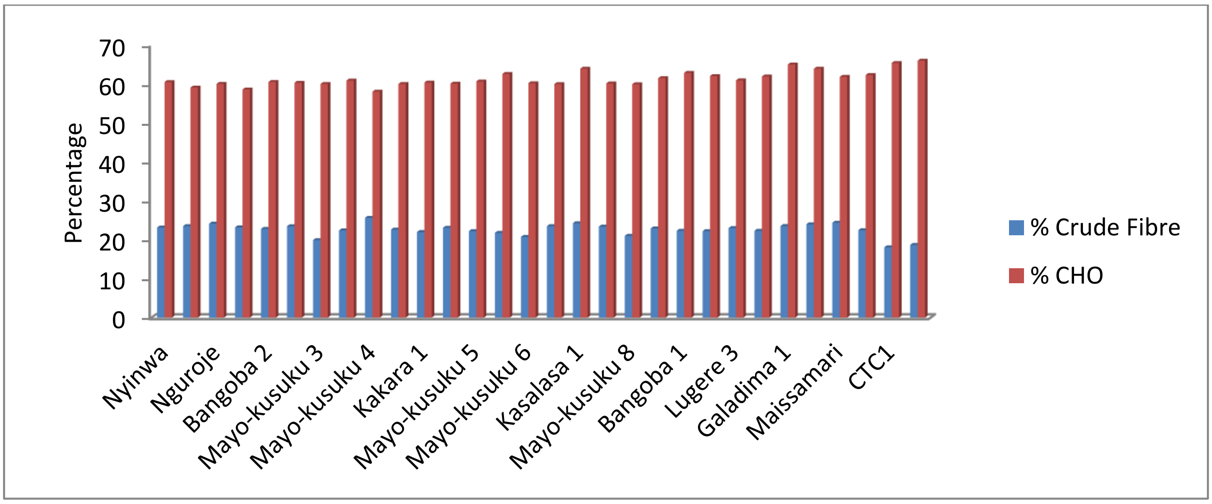

Figure 2: Crude fiber and Carbohydrate content of black tea samples

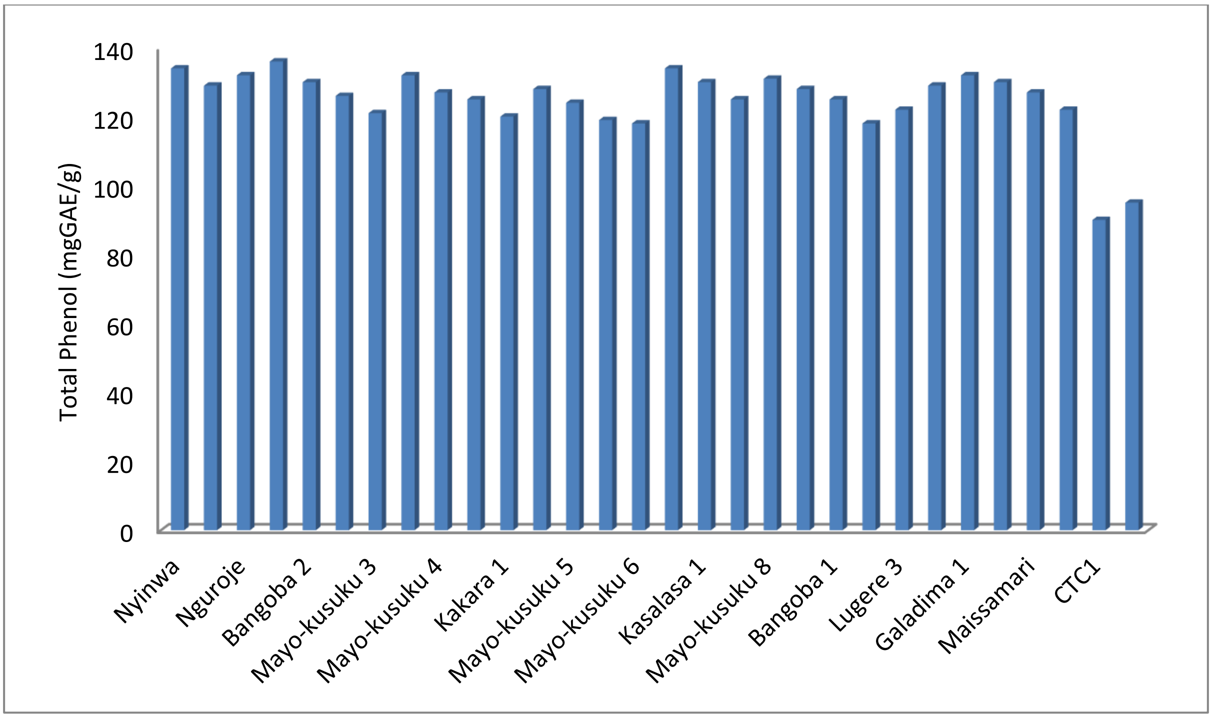

Figure 3: Total phenolic compounds in black tea samples

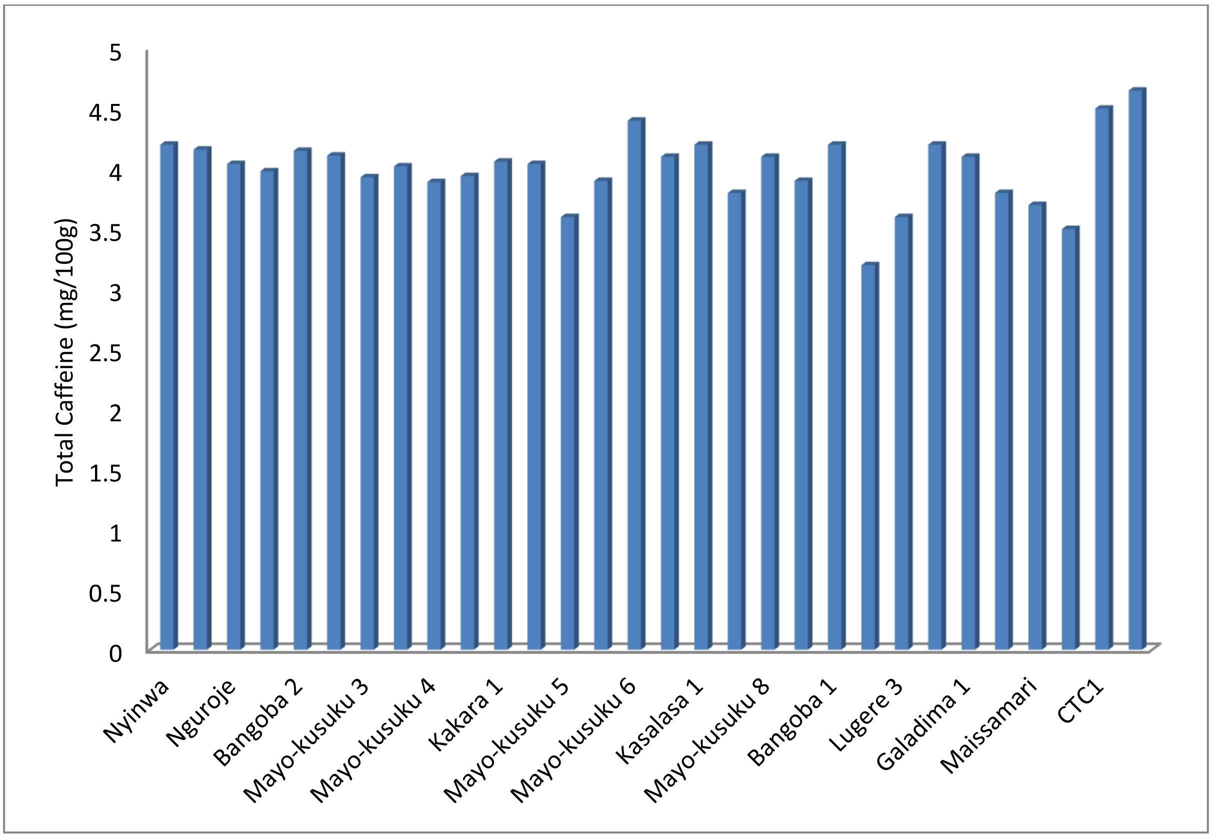

Figure 4: Total Caffeine content of black tea samples

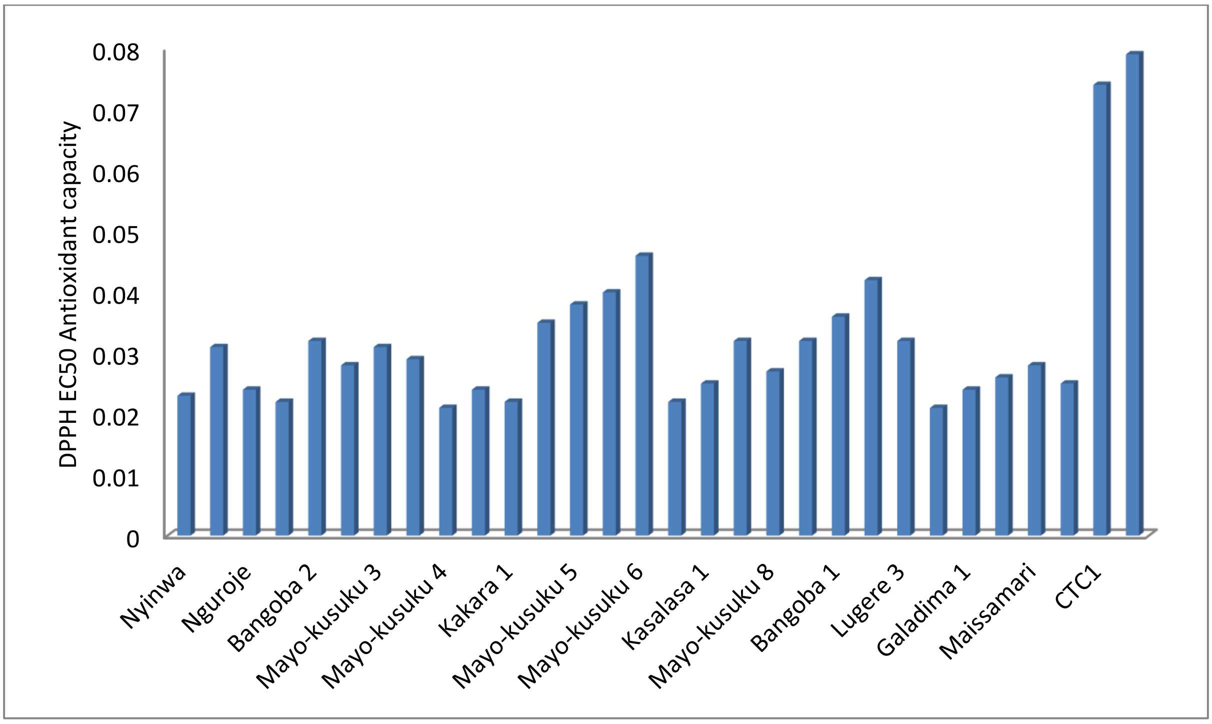

Figure 5: DPPH antioxidant capacity of black tea samples

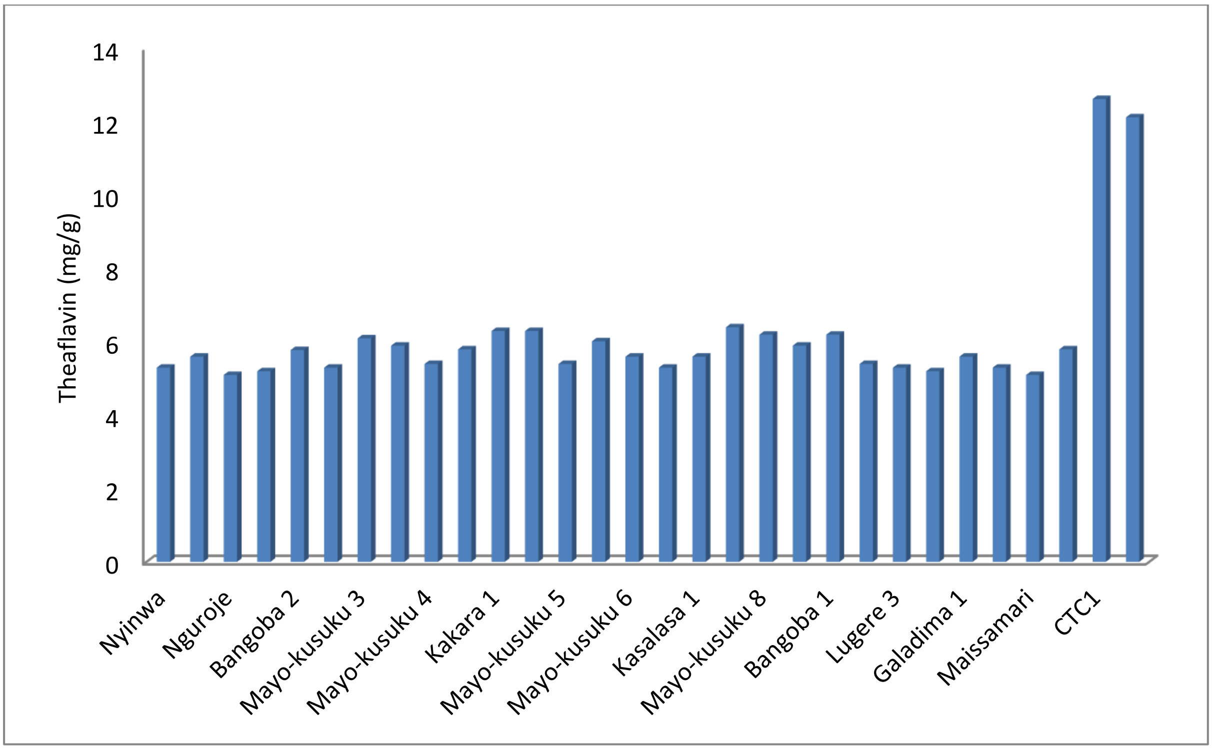

Figure 6: Theaflavin content of black tea samples

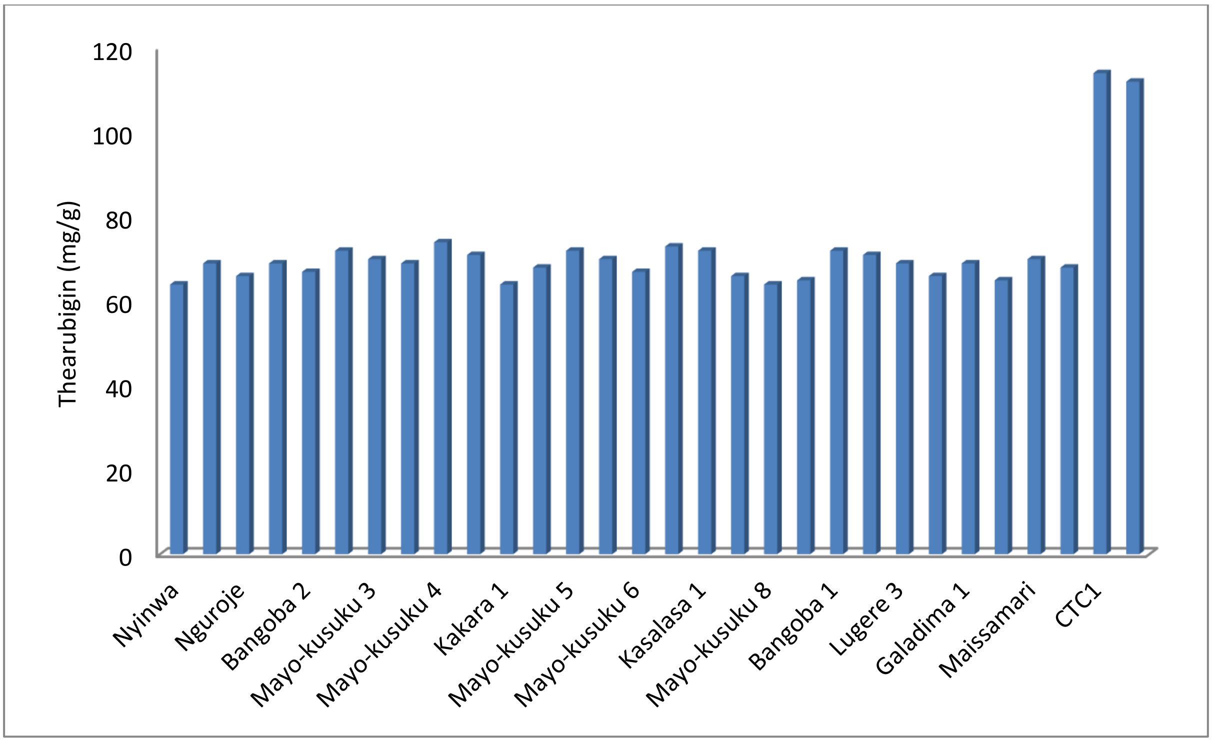

Figure 7: Thearubigin content of black tea samples

4.0 DISCUSSION

Crude Protein: Protein as a class of food is needed in human body to stay healthy. Its metabolism is a critical part of the processes that fuel human energy and carry oxygen throughout the body. It helps in the synthesis of antibodies that fight off infections, illnesses and helps keep cells healthy and creates new ones. Protein content in plant sample gives a reflection of nitrogen content of the soil. Result reveals that, the protein contents of the locally processed black tea compare favorably with tea samples from tea companies where industrial crush, tear and curl (CTC) machine was used in the tea production. The range of protein content of the evaluated tea samples is similar to the range of protein (0.30 – 1.06%) reported by [7] from the analysis of four different brands of tea. [8] similarly reported a range of 0.87 – 1.41% for protein content of commercial black tea in Pakistan.

Crude fiber: Crude fiber is the insoluble residue in plant sample after acid and alkaline hydrolysis. It is mainly a measure of the quantity of indigestible cellulose present in food. The values of crude fiber obtained in the analysis of the various tea samples are higher than 16.5% which is the international standard for crude fiber content of black tea [9]. The high percentage of crude fiber in the tea samples reflects the quality of raw material used in the production of the black tea. For black tea production, the ideal protocol and practice is to harvest the bud and the two leaves closer to the bud commonly known as 2 leaves and 1 bud. In a bid to maximize the use of available raw material and consequently maximize profit, almost all tea farmers and local tea processors go beyond the 2 leaves and 1 bud. On the average, 3-4 leaves and 1 bud are plucked for the processing of black tea. The practice of plucking matured leaves with the bud ultimately imparts a high cellulosic burden on the finished product. On the other hand, the crude fiber content of the two commercial teas produced by CTC machine had fiber content of 16.0 and 16.5%. The difference in the fiber content of the locally made black tea and the CTC processed black tea borders on two factors; maturity of harvested tea leaves and availability of facility to separate fiber from the finished products. In the various tea producing companies, harvesting of tea leaves may have been restricted to 2 or 3 leaves and 1 bud while local tea processors use matures tea leaves (3-4 leaves and 1 bud) bought from tea farmers who are paid on the basis of total weight of fresh tea leaves supplied. When overgrown leaves are used as raw material for tea production, the fiber content of the finished product will be excessively high while other nutritional and quality parameters may be low per unit weight of the product. The second factor is the availability of standard separation facility in the tea company that removes materials with high fiber or cellulose from the finished product during sieving and grading of the made black tea. Though the local tea processors also carry out sieving of the processed tea, they do not have access to equipment of high level of precision like the tea companies to separate high fiber materials from the made tea. This limitation in a way, may affect the quality of the finished product. [10] reported a range of 8.82 – 15.47% for crude fiber in black tea prepared from clonal materials in Nepal. [8] reported crude fiber content of some commercialized tea in Pakistan ranging from 11.23 –17.21%. According to the authors, the tea samples with high fiber content must have been produced with harvested raw tea leaves that contained tea plant stem and overgrown tea leaves. The unhealthy agronomic practice in tea harvesting procedure has a way of undermining the quality of tea made from such process.

Moisture: Moisture content of food material is the amount of water molecule that is retained in the material after processing. Moisture content is a vital quality parameter for any food product sold in dry form. Moisture content of food material is a factor that determines the shelf life if no chemical or biological preservative is added. Microorganisms responsible for food spoilage find it easier to grow on food materials that are moist than food substances with very little or no moisture. Due to the susceptibility of food material to microbial contamination and spoilage, Robinson and [11] suggested that, moisture content of tea for commercial purpose be kept below 6.5%. In a general evaluation conducted by [12], he reported that, commercial tea had moisture content of 7.0 – 8.5%. In the study being reported, data showed that, CTC1 and CTC 2 which are commercial black tea processed industrially with Crushing, tearing, and curling (CTC) action, had low moisture compared with the black tea produced by the local tea processors on the Mambilla Plateau. The major factor responsible for the distinction between the moisture content of the locally processed tea and industrially processed is the availability of a drying section furnished with heat drying compartment within the production line. Conversely, the local tea processors do not have access to functional equipment for drying the macerated tea leaves after fermentation. Rather, they spread the materials on woven mats and solely rely on the energy from the sun to affect the drying. Mambilla Plateau is characterized by high rainfall and humidity. The two weather conditions (rainfall and humidity) associated with moisture and the sole reliance on direct sunshine for tea drying make the attainment of 6.5% moisture almost impracticable during the wet season. If low moisture content of processed tea will be achieved by local tea processors under the current processing methodology and limited facility, the production must be done in the dry season and that will make their productivity seasonal. Yadav et al., [10] reported a range of 5.32 – 5.39% moisture for black tea produced from clonal materials in Nepal while [7] reported a range of 2.46-7.21% moisture content in fifteen commercial black tea brands in Pakistan. The variation in moisture content of different commercial tea brands across different countries suggests the challenge in attaining uniformity in moisture content of black tea globally. From industrial production point of view, it might be difficult for all tea companies in various nations to record same efficiency for CTC machines, dryers, quality control, quality assurance and packaging. The variation in the aforementioned parameters in the production and value chains will invariably lead to differential moisture content in the finished products. Another reason why it is difficult for all processed or packed black tea to have uniform moisture content is the ability of processed tea to absorb moisture from the environment. Processed black tea has a high capacity to absorb moisture from the environment. It is somewhat hygroscopic in nature. This is the main reason why some individuals put tea bags in shoes to absorb unpleasant odor and moisture that may be present. In a situation where the black tea is properly dried to standard after passing through the industrial dryer, if the product is left for too long before packaging takes place, the moisture content may not remain the same due to the possibility of moisture absorption from the surrounding. To minimize the absorption of moisture from the environment, packaging of finished tea should be done in air-tight materials without delay.

Fat: Fat content of plant material is the fraction of the food material that is soluble to lipid solvent. Fat in plant mainly consist of triglycerides made up of fatty acids bonded to glycerol molecule. Property of the fat is determined by the types of fatty acids associated with the triglyceride's molecule in the plant. Among the common fatty acids in tea leaves are linolenic acid, linoleic acid, oleic acid and palmitic acid. [8] reported a range of 0.94 – 2.15% fat content for fifteen commercial tea brands in Pakistan while a range of 3.6 – 5.80% fat content was reported by [7] in four imported commercial tea brands in Nigeria.

Ash: Ash content of plant material is the minerals and inorganic substances left after the sample is heated to a high temperature that removes all organic matter, volatiles and moisture from the plant sample. Data on the ash contents of the various samples showed that, the locally processed tea compared favorably with the industrially processed tea with respect to percentage of ash in the samples. Mineral content of processed tea is a function of the macro and micronutrients status of the soils where the harvested tea samples were obtained. If the nutrients in the soil are adequate for tea cultivation, the reflection will be obvious in the ash content of the processed tea. Results showed that, 73% of the evaluated black tea samples fell within the recommended ISO 1575 standard (4.0 -8.0 %) for total ash in black tea. The variability in the ash content of the locally processed black tea samples is a reflection of variation in macro and micronutrients contents of the soils where tea is grown on the Mambilla plateau. [10] reported a range of 6.30 – 7.53% of total ash in black tea made from different clones in Nepal. The range of total ash in black tea (1.00 – 2.50%) reported by [7] is lower than what was obtained in the study. On the other hand, a similar but lower range of total ash (3.29 – 5.86%) than what was obtained in the reported study was recorded by [8] for 15 commercial tea brands in Pakistan.

Carbohydrate: Carbohydrate is a bio-molecule which consists of carbon, hydrogen and oxygen atoms. Generally, in proximate analysis, carbohydrate in food materials is determined by the difference between 100% and the summation of the percentages of crude fiber, crude protein, moisture, ash and fat contents of food. The carbohydrate content of food is used in determining the amount of energy in calorie from its consumption. Proximate analysis of the tea samples showed that, carbohydrate had the highest proportion compared to other parameters. This implies that, the consumption of black tea can be a source of energy for the consumers of the product. The higher percentage of carbohydrate in tea samples compared with other proximate parameters is mainly due to the fact that, plants generally store energy synthesized during photosynthesis in the form of carbohydrates in plant. This is expected because photosynthesis takes place in the leaves of plants.

Total phenol: Polphenols are plant based secondary metabolites generally involved in the defense against ultraviolet radiation and pathogen infestation in plant. They boost heart health and immunity when consumed by human. The obtained low polyphenolic content of the commercial tea sample was due to the conversion of polyphenols to other biochemical compounds which impart flavor, aroma and color on black tea. Catechins are the main polyphenols in green tea. Catechins derivatives include epigallocatechin-3-gallate, epicatechin, gallocatechins, epigallocatechin, epicatechin-3-gallate and gallocatechin gallate. During fermentation, polyphenols (catechins) are converted through oxidation to theaflavin (TF) and Thearubigin (TR). Apart from the oxidation of catechins to TF and TR, some volatiles compounds are generated during fermentation which includes essential oils and amino acids. The amino acids react with orthoquinone (oxidized form of catechin) in fermented tea leaves to form precursors of sweet aroma in tea [13]. The process of fermentation and the condition under which fermentation occurs are important factors that determine the quality of black tea that will be produced at the end of tea processing. Fermentation involves series of biochemical reactions which involves enzymes. The physical state of the tea leaves, the temperature under which fermentation takes place and enzymatic conditions are important factors that influence the rate of fermentation, the type and quality of fermentation products at the end of black tea production. The local tea processors do not have access to CTC machines because of the huge financial involvement in its acquisition. Rather, they use locally fabricated machines to macerate the tea leaves in order to break the cell walls of the leaves and expose the surfaces of the fragmented leaves to fermentation process. After the tea leaves are crushed and macerated, the processors pile them up in the form of heaps and leave them to undergo fermentation naturally. The condition under which the fermentation is done does not create an ideal environment for adequate conversion of polyphenols to other biochemical compounds. Based on the limitation of the grinding machine to adequately reduce tea leaves into uniform tiny particles, the surface area on which the enzymes acted was limited. Hence, more un-oxidized polyphenolic compounds were retained in the locally processed black tea compared to the one produced under the action of the CTC machine which effortlessly crushes, tears and curl the fresh tea leaves. The CTC machine is furnished with series of cylindrical rollers with serrated blades that do the crushing, tearing and curling of tea leaves into small, even-shaped pellets. Though there are no strict conditions for tea fermentation, industrial production of black tea is done under controlled fermentation at the temperature of 24 – 29^{o}C with adequate supply of oxygen during the process of fermentation. On the other hand, the locally processed black undergoes fermentation within the heaps made with crushed tea leaves by the local processors. Difference in the conditions under which fermentation is done by the tea companies and local processors are responsible for the variation in quality of the black tea from both sources. [14] reported a range of 122 – 171g/kg polyphenol in black tea produced in Iran while [15] reported a range of 75.63 – 128 mg GAE/g in novel tea produced with tea leaved from South Korea. Similarly, [16] reported a range of 500.85 – 794.31mg/g total polyphenol in black tea processed in Indonesia.

Total Caffeine: Caffeine is a naturally occurring central nervous system stimulant and a trimethyl xanthine. It creates mental alertness and relieves pain. Caffeine is a pyrine alkaloid. Different parts of tea plant contain varying amount of caffeine. Generally, young tea leaves contain higher amount of caffeine than older leaves and this is the main reason why the concentration of caffeine in green tea is expected to be higher than black tea. The standard recommendation for the production of green tea is to harvest a bud and 1 leaf closest to the bud (1 leaf and a bud). To produce black tea, the standard recommendation is to harvest a bud and the 1st and 2nd leaves next to the bud (2 leaves and a bud). In practice, processing of tea in large quantity involves mixing tea leaves of different ages and maturity. Hence, the variation in caffeine content of made tea largely dependents on the ratio of matured tea leaves to young leaves in any production batch. However, if the standard operating procedure of tea leaf harvest is adhered to, the variation in caffeine content in made tea should be minimal irrespective of production batch and production location. The level of caffeine (3145 – 13986 mg/100g) reported by [15] in novel fermented tea from Korea is much higher that the values obtained in the locally processed black tea made on the Mambilla Plateau, CTC 1 and CTC 2.

DPPH free radical scavenging: Polyphenolic content of the investigated tea samples was found to be inversely proportional to DPPH EC_{50}. DPPH (2,2-diphenyl-1-picrylhydrazyl) assay is a method commonly used to measure the ability of chemical compounds to act as a free radical scavenger or hydrogen donors which allow the evaluation of antioxidant capacity of foods to be determined. The assay can also be used to quantify the antioxidant capacity in complex biological systems either solid or liquid samples. In the DPPH free radical scavenging assay, antioxidant react with DPPH (hydrogen acceptor) which has a deep violet color in solution and turns it yellow-colored diphenyl picrylhydrazine. If there is no antioxidant in the sample being investigated, the purple color of DPPH will remain unchanged. The rate of reduction of DPPH determines the antioxidant activity of the sample being examined. Materials or substances with high antioxidant capacity have the potential to prevent the damaging effects of free radicals which initiate the development of cancer in a living system. Infused tea is well known for its antioxidant capacity due to the types of polyphenols in tea plant. EC_{50} can be defined as the stoichiometric maximum concentration of antioxidants needed to reduce half of the DPPH free radical ($DPPP^{*}$) at steady state. This is known as half-maximal effective concentration. In pharmacology, the potency of a compound is expressed as the half-maximal effective concentration (EC_{50}), which refers to the concentration of a drug that induces a response halfway between the baseline and maximum. Polyphenols biochemically act as antioxidants by donating electrons or hydrogen to free radicals thereby, neutralizing their damaging effects in living system. From the result, CTC1 and CTC 2 with DPPH EC_{50} of 0.074 and 0.079 respectively will be needed in more quantity to provide equal reducing activity of the black tea produced by local processors. The lower antioxidant capacity of the CTC processed samples as compared with samples from the local processors is based on the oxidation of catechins in crushed tea leaves to theaflavins and thearubigins during fermentation. Due to inadequate or incomplete fermentation in the locally processed tea, certain amount of catechins and its derivatives were retained in the tea samples. The presence of catechins and their associated bioactivities in the locally processed black tea imparts the product with higher antioxidant capacity than the CTC processed tea. In the industrially processed tea, most of the catechins a greater proportion of the catechin is oxidized to theaflavins and thearubigins with lower antioxidant capacity. [15] reported a DPPH range of 0.029 – 0.077 in the analysis of tea sample from Korea.

Theaflavins and Thearubigins: Both theaflavin and thearubigins are biochemical products of enzymatic oxidation of catechin by polyphenol oxidase (PO) and peroxidase in an aerobic environment [17, 18]. Theaflavin and thearubigins are major oxidative products of catechins that impart varieties of quality parameters on black tea. They are non-volatile large molecular compounds formed via condensation reaction when catechin is oxidized. Both theaflavin and thearubigins are the chemical compounds responsible for color and taste of black tea liquor [19]. Theaflavin determines the brightness, briskness and quality of tea liquor while thearubigins determines the color, taste and body of the tea liquor [20]. Theaflavin are responsible for orange-red color pigment in tea liquor while thearubigins are responsible for the reddish-brown pigment of black tea liquor [21]. The conditions under which theaflavin and thearubigin occur during fermentation have significant impact on the quality of tea liquor. The process, time, oxygen, relative humidity and pH affect the quality of tea being produced [22]. Duration of fermentation plays a key role in the quality of black tea [23]. Quality of infused black tea depends on the duration of fermentation, degree of maceration, degree of withering and standard plucking. Black tea quality parameters such as astringency, brightness, briskness and liquor strength all attain their optimum height at different times. Hence, optimization has to be determined to get the overall best quality [24]. Ideally, fermentation time for CTC processed tea varies from 55 – 110 minutes while orthodox fermentation varies from 2 – 4 hours [25]. The shorter time for CTC fermentation is due to the extensive cell rupturing which makes large surface of the materials exposed to enzymes and oxygen. In the case of the local tea processors, the capacity and efficiency of the locally fabricated grinding machine to uniformly rupture the cells of the tea leaves is limited. Consequently, lesser surface area is made available for enzymes and oxygen during fermentation. In such situation, the amount of theaflavin and thearubigin can never be the same with the black tea fermented using industrial machines under optimum conditions. The singular difference in the physical state of the tea material towards fermentation was enough to cause disparity in the quality parameters of tea made with CTC machine and locally processed. Conversion of catechin to TF and TR increases with fermentation reaching optimum level at a point. Once the optimum level is attained, further fermentation leads to degradation of oxidation products [24, 21]. According to [26], prolonged fermentation leads to gradual degradation of theaflavin to thearubigin and this makes the body of tea liquor becomes thick. Hence, over-fermented tea lacks several desirable qualities. A quality cup of tea requires the maintenance of an optimum ration of theaflavin and thearubigin (1:10) [27]. The lower level of theaflavin and thearubigins in locally processed tea compared with CTC processed could also be a consequence of the departure of the conditions under which local tea fermentation is currently done from the ideal. The ability of local tea processors to create optimum fermentation conditions which will lead to the oxidation of catechins to theaflavin and thearubigin in the right quantity and ratio is difficult considering the education level of most of the processors, financial capacity, available machinery, available processing equipment, lack of dryer, lack of government support and lack of electricity. For the quality of black tea produced by the local tea processors on the Mambilla Plateau to attain international standard, there must be substantial provision of support in terms of machinery, dryers, CTC machine, electricity and adequate training by government, private companies, corporate organizations and individuals for the local tea processors. This will go a long way in encouraging small and medium enterprise among tea growers and local tea processors on the Mambilla Plateau. It will also strengthen their financial capacity as many tea merchants will be willing to buy their products when the quality meets international standard.

5.0 CONCLUSION

The fat, ash, protein and carbohydrate content of the locally processed black tea were favorably comparable with the CTC processed black tea. Locally processed black tea on the Mambilla plateau was high in crude fiber which showed that, standard procedure of harvesting 2 leaves and 1 bud is not adhered to, by local tea processors and tea farmers who sell fresh tea leaves to the local processors. Moisture content of locally made tea is currently higher than required as this will subject the product to early microbial contamination and consequently reduce its shelf life. Theaflavin and thearubigin contents of the locally processed black tea were much lower than the CTC processed tea due to inadequate physical state of the crushed tea leaves and environmental conditions for adequate fermentation. The quality deficit in term of high moisture content and high crude fiber content stand as drawback for the locally processed tea. This could have led to early caking of the products with characteristic off-flavor due to rancidity. In such situation tea merchants may not be willing to continue the patronage until the quality improves. The low level of theaflavin and thearubigin in the locally processed black tea is another quality deficit that must have contributed to the low patronage by tea merchants in recent times. The two oxidation products of catechins are the determinants of color, flavor, aroma, body, and brightness in black tea. Any tea that lacks adequate TF and TR cannot produce the desired brightness, flavor and aroma when infused. The absence of these quality parameters in any brand of black tea could lead to loss of interest in tea drinkers. They will naturally opt for other types that will give them the desired flavor, aroma and satisfaction. This might be the exact reason why the demand for the locally processed tea had dropped.

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Conflicts of Interest

The authors declare that there is no conflict of interest in the publication.

Contribution of the authors

The first author conceived the idea of the study, designed the experiment, coordinated sample collection and wrote the manuscript. Second and third authors coordinated laboratory analysis of the samples.

6.0 REFERENCES

[1] Preedy VR. Tea in Health and Disease Prevention; Elsevier: Amsterdam, The Netherlands. Academic Press, 1st edition, 2013.

[2] AOAC, Official methods of analysis. 17th Ed. Association of Analytical chemist, Horowitz Maryland, 2000; pp. 12-20

[3] Jaradat NA, Hussen F M, and Al Ali A. Preliminary phytochemical screening, quantitative estimation of total flavonoids, total phenols and antioxidant activity of Ephedra alata Decne, J. of Mat. and Environ. Sci. 2015;6 (6): 1771–1778.

[4] Vignoli J A, Bassoli G, and Benassi MT. Antioxidant activity, polyphenols, caffeine and melanoidins in soluble coffee: the influence of processing conditions and raw material, Food Chemistry, 2011;124 (3): 863–868.

[5] Belay K, Ture M, Redi, and A Asfaw. Measurement of caffeine in coffee beans with UV/Vis spectrometer, Food Chemistry 2008; 108(1): 310–315.

[6] Borse B, Jagan L, Mohan Rao. Novel bio-chemical profiling of Indian black teas with reference to quality parameters, J. of Microbial and Biochem. Technol. 2012;14, 1–16.

[7] Ifemeje JC, Ifemeje MO, Egbuna C, and Olisah MC. Proximate, Phytochemical and Antioxidant Mineral Compositions of Four Different Brands of Tea. Advance J. of Grad. Res. 2020; 8(1): 1-7.

[8] Muhammad Adnan, Asif ahmad, Anwaar Ahmed, Nauman Khalid , Imran Hayat and Iftikhar Ahmed. Chemical composition and sensory evaluation of Tea (Camellia sinensis) Commercialized in Pakistan. Pak. J. of Bot. 2013;45(3): 901-907

[9] ISO (International Standard Organisation) 3729. Black tea definition and basic requirements. International Standard Organization 1986.

[10] Yadav KC, Ashok Parajuli, Bishnu Bahadur Khatri, and Lila Devi Shiwakoti. Phytochemicals and Quality of Green and Black Teas from Different Clones of Tea Plant. J. of Food Qual. 2020; 1-13

[11] Robinson J M, and Owuor P O. Tea: Analysing and testing, in The Encyclopaedia of Food Sci. Food Technol. and Nutr, R. Macrae, R. Robinson, and M. Sadler, Eds., 1993; pp. 4537–4542, Academic Press, London, UK.

[12] Mythili K, Reddy CU, Chamundeeswari D, and Manna P. Determination of total phenol, alkaloid, flavonoid and tannin in different extracts of Calanthe triplicate, J. of Pharmacognosy and Phytochemistry. 2014; 2 (2):40–44.

[13] Bhattacharyya N, S Seth, B Tudu, P Tamuly, A Jana D, Gosh R, Bandyo padhyay, and M Bhuyan. Monitoring of black tea fermentation process using electronic nose. J. of Food Engine 2007; 80:1146-1156.

[14] Abdolmaleki F. Chemical analysis and Characteristics of black tea produced in North of Iran. J. of Food Biosci and Technol. 2016; 6(1): 23-32.

[15] Tao Tong, Ya-Juan Liu, Jinhong Kang, Cheng-Mei Zhang, and Seong-Gook Kang. Antioxidant Activity and Main Chemical Components of a Novel Fermented Tea. Molecule 2019;24: 1-14.

[16] Tuty Anggraini, Neswati, Ririn Fatma Nanda and Daimon Syukri. Effect of Processing on Green and Black Tea DPPH Radical Scavenging Activity, IC50 Value, Total Polyphenols, Catechin

[17] Chen H, Shurlknight K, Leung T, and Sang S. Structural identification of theaflavin trigallate and tetragallate from black tea using liquid chromatography/electrospray ionization tandem mass spectrometry. J. of Agric. and Food Chem. 2012; 60: 10850-10857

[18] Samanta T, Cheeni V, Das S, Roy A B, Ghosh B C, and Itra A. (2015). Assessing biochemical changes during standardization of fermentation time and temperature for manufacturing quality black tea. J. of Food Sci. and Technol. 2015; 52(4): 2387-2393

[19] Obanda M, Owour P O, and Mang'oka R. Changes in the chemical and sensory quality parameters of black tea due to variations of fermentation time and temperature. Food Chemistry 2001; 75: 395-404

[20] Jolvis Pou, KR. Fermentation. The Key Step in the Processing of Black Tea. J. of Biosystem Eng. 2016; 41(2): 85-92

[21] Stodt U W, Blauth N, Niemann S, Stark J, Pawar V, Jayaraman S, Koek J, and Engelhardt UH. (2014). Investigation of processes in black tea manufacture through model fermentation (oxidation) experiments. J. of Agric. and Food Chem. 2014; 62: 7854-7861.

[22] Cloughley J, and Ellis R T. (1980). Effect of pH modification during fermentation on the quality parameters of Central African black teas. J. of the Sci. of Food and Agric. 1980;31: 924–934

[23] Muthumani T, and Kumar R S S. Influence of fermentation time on the development of compounds responsible for quality in black tea. Food Chemistry 2007;10: 98-102

[24] Sanyal S. Tea manufacturing manual. Tea Research Association, Tocklai Experimental Station, Jorhat. 2011.

[25] Sharma V, and Rao L J M. (2009). A Thought on the biological activities of black tea. Critical Rev. in Food Sci. and Nutr. 2009; 49: 379-404

[26] Borah S, and Bhuyan M. Non-destructive testing of tea fermentation using image processing. Insight-Non-Destructive Testing and Condition Monitoring 2003; 45: 55-58.

[27] Gill G S, Kumar A, and Agarwal R. (2011). Monitoring and grading of tea by computer vision- A review. J. of Food Eng. 2011;106:13-19