



Determination of Green Tea Recovery Percentage and Its Relation to Different Weather Parameters

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Authors' contributions

This work was carried out in collaboration among the authors. Author MRA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MIH managed the literature searches and gave the proper direction about the experiment. Author MRUR helped to make the data analysis and wrote the manuscript draft copy. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Green tea is one of the most popular drinks and millions of cups are consumed every day in entire world. In Bangladesh, people mainly prefer CTC (Crush-Tear-Curl) black tea but now-a-days health conscious people are being habituated to green tea due to its beneficial effect to health. Since our green tea production is very little compared to black tea production, our concept and knowledge about green tea is also very low. This experiment was conducted with two main objectives: to determine the green tea recovery percentage and to find its relation to different weather parameters.

Study Design: This experiment was conducted by following Factorial Completely Randomized Design (CRD) with four replications.

Place and Duration of Study: This experiment was conducted at Miniature Factory of Bangladesh Tea Research Institute (BTRI) Sreemangal, Moulvibazar-3210 from March 2017 to November 2017.

Methodology: BTRI recommended green tea manufacturing process (Green Leaves→ Steaming→ Cooling→ Rolling→ Drying) was followed in this experiment to calculate the recovery percentage. Weight of green leaves after each stage and recovery percentage were calculated. Monthly weather data of four parameters: temperature (°C), rainfall (mm), relative humidity (%) and sunshine hour were also collected. Correlation Coefficient (r) was calculated by Pearson's mathematical formulation to quantify the degree of relationship. Linear regression equation was also generated to predict recovery percentages against different weather parameters only when the relationship was significant.

Results: In case of BTRI recommended green tea manufacturing process the average recovery percentage was 19.19% with an average moisture content of 3.72%. Among four weather parameters, temperature (°C) has negative insignificant (correlation coefficient, $r=-0.43$ and $P=0.2523$) relation on recovery percentage. But there was a strong significant ($P=0.000146$) negative effect ($r=-0.942$) of rainfall on recovery percentage. While a moderate non-significant ($P=0.322807$) negative relation ($r=-0.37$) of relative humidity and a considerable high positive non-significant ($P=0.073687$) relation ($r=0.62$) of sunshine hour on recovery percentage was found in this study.

Conclusion: Green tea recovery percentage was 19.19% with an average moisture content of 3.72% which can be different with different weather conditions in every month. Among four weather parameters, mainly rainfall was responsible for the variation of recovery percentages in different months.

Keywords: Green tea; recovery percentage; temperature; rainfall; relative humidity and sunshine hour.

1. INTRODUCTION

Next to water, tea is one of the most widely consumed beverages in the world [1,2]. Normally, tea can be categorized into three groups: green tea (unfermented), Oolong tea (partially fermented) and black tea (fully fermented) based on tea processing [3]. Different kinds of teas are manufactured in different countries based on taste, habit and culture of people. For example, in Bangladesh, people mainly consume CTC black tea, whereas people of Sri Lanka prefer orthodox tea. China and Japan are the world's leading producers of green tea [4]. Publicized studies on the health benefits of green tea have only been available since the 1990's. However, green tea's popularity in the West can be attributed to the growing interest in its potential health benefits [5].

Green tea is one of the most popular drinks and millions of cups are consumed every day in entire world [6]. Green tea has been reported as a rich source of catechin and its derivatives that contribute to antioxidant capacity and organoleptic properties [7]. There are basically two types of green tea available in the world that includes the Japanese style steamed green tea and the Chinese style parched (fired) green tea with the difference in blanching [8].

Tea production in Bangladesh was 96.07 million kg in 2019. 99% of these tea was CTC black tea

and only 1% was green tea [9]. The ratio of made tea to green leaf is termed as "recovery percentage" alternatively, as "out turn". In case of CTC black tea, generally 22.5 kg of made tea is expected from every 100 kg of green leaf. That means an average in whole season tea recovery percentage for CTC black tea is 22.5% [10]. But manufacturing process of black tea and green tea is different, so there is a chance to have a difference in recovery percentage also. This experiment was conducted with two main objectives: to determine the green tea recovery percentage and to find its relation to different weather parameters.

2. MATERIALS AND METHODS

This experiment was conducted at Miniature Factory of Bangladesh Tea Research Institute (BTRI) Sreemangal, Moulvibazar-3210 from March 2017 to November 2017. Leaves of standard plucking and uniform quality of BTRI released clone BT2 were used in this experiment. Two leaves and a bud were plucked from BTRI Experimental Farm for obtaining good quality of green tea. For manufacturing green tea, BTRI recommended manufacturing process [11] was followed: Green Leaves→ Steaming→ Cooling→ Rolling→ Drying. As first stage of processing (Steaming), freshly plucked green leaves were steamed by water steam of 100°C for 30-40 second. Steaming process is beneficial in retaining the antioxidant components,

appearance and texture of the dry leaf, decreasing the process time [12]. At second stage (Cooling), steamed leaves were put for cooling and centrifuging. During this process the wet leaves were flip-flopped continuously under cooling fan for about 30 minutes. In this period the excess water in leaves were evaporated and the leaves became sticky. At third stage (Rolling), these sticky leaves were then put into rolling machine. Leaves were rolled in a rolling machine for about 10 minutes with different pressure. Optimum rolling is necessary because less rolling results uneven crushing and more rolling cause loss of chemicals resulting improper mixing of chemical with enzyme [13]. When rolled leaves became twisted and no juice was secreted from the leaves it became perfect for drying. At final stage (Drying), rolled leaves were put for drying in drying machine at 93-99° temperature for 20-30 minutes. From March 2017 to November 2017, in each month green tea was processed on weekly basis (as four replications in a month) to calculate more accurate recovery percentage. Initially 1000 gm fresh green leaves were used for manufacturing process in each replication. Weight of green leaves were calculated after each stage of processing period. To calculate recovery percentage of green tea following equation was used:

$$\text{Recovery Percentage (\%)} = \frac{(\text{Weight of leaves after drying stage})}{(\text{Weight of initial fresh green leaves})} \times 100$$

Moisture content of dried and processed green tea was calculated by Precisa (EM120-HR) moisture analyser. Data under study were statistically analyzed by IBM SPSS Statistics version 25 software wherever applicable. The experiment was conducted in controlled condition at Miniature Factory of BTRI and arranged in Factorial Completely Randomized Design (CRD) with four replications. The Analysis of Variance was calculated and means were compared by the Duncan's Multiple Range Test (DMRT).

To find the relationship between green tea recovery percentage and weather condition, four (4) weather parameters were considered, these are: temperature (°C), rainfall (mm), relative humidity (%) and sunshine hour. Monthly weather data of these four parameters were collected from Weather Station of BTRI Experimental Farm. Correlation analysis was done to find the nature of relationship between

recovery percentage and weather condition. Correlation Coefficient (r) was calculated by Pearson's mathematical formulation to quantify the degree of relationship [14]:

$$\text{Correlation Coefficient (r)} = \frac{\sum k}{\sqrt{\sum m}} \quad [\text{Where, } k=(x-\bar{x})(y-\bar{y}), m=(x-\bar{x})^2, n=(y-\bar{y})^2, n=\text{Number of observations, } x=\text{Measures of Variable 1 and } y=\text{Measures of Variable 2.}]$$

The correlation coefficient was used to interpret the relationship based on its value [15]. When the relationship was significant, only then linear regression equation [16] was generated to predict the response of recovery percentage against weather parameters.

3. RESULTS AND DISCUSSION

3.1 Determination of Recovery Percentage of Green Tea

Weight of green leaves varies upon processing stages of green tea. In steaming stage, weight was slightly increased due to accumulation of water steam to the leaves. But after steaming, in every stage (Cooling, Rolling and Drying) weight loss was occurred. Weight was drastically reduced at drying stage. Although maintaining moisture content in drying stage was quite impossible because whole process was done manually but in this experiment the moisture content was kept below 4% as it is recommend for better storage without degrading its quality. From Table 1, it was observed that highest out turn or recovery percentage was found in November (21.22 %) followed by March (19.84 %) while low recovery percentage was found in June (17.68 %). Although, same quality and quantity of green leaves were used for same manufacturing procedure throughout the experiment, the only difference was in leaves which were plucked in different weather conditions. So, there was a chance to have a relation between recovery percentage and weather parameters that which described in second section (3.2) of this experiment. Finally it was found that, in case of BTRI recommended manufacturing process, the average recovery percentage (%) of green tea was 19.19 % with an average moisture content of 3.72% (Table 1). In Sri Lanka, for orthodox green tea processing method, the recovery percentage of green tea was found to be 18% with an average moisture content of 2-3% [17].

Table 1. Month wise recovery percentage and processing stage wise weight (gm) of green tea

Month	Weight of green leaves Initial Fresh weight	Weight after Steaming stage	Weight after Cooling stage	Weight after Rolling stage	Weight after Drying stage	Moisture content of processed tea (%)	Recovery Percentage (%)
March	1000 a	1000.045 a	920.29 a	785.80 a	198.4 b	3.36 c	19.84 b
April	1000 a	1000.032 a	921.52 a	787.64 a	179.1 de	3.94 a	17.91 de
May	1000 a	1000.030 a	921.42 a	784.29 a	193.3 bc	3.64 b	19.33 bc
June	1000 a	1000.055 a	922.31 a	786.00 a	176.8 e	3.73 ab	17.68 e
July	1000 a	1000.036 a	925.18 a	784.21 a	197.3 bc	3.84 ab	19.73 bc
August	1000 a	1000.034 a	921.02 a	782.93 a	192.7 c	3.81 ab	19.27 c
September	1000 a	1000.029 a	920.94 a	784.35 a	182.7 d	3.62 bc	18.27 d
October	1000 a	1000.032 a	919.89 a	788.20 a	194.6 bc	3.67 b	19.46 bc
November	1000 a	1000.028 a	922.20 a	786.94 a	212.2 a	3.85 ab	21.22 a
Average	1000	1000.036	921.64	785.59	191.90	3.72	19.19
LSD at 5% level of significance	-	-	-	-	5.4687	0.2666	0.5469

The mean difference is significant at $P < 0.05$. Letters indicate values within the same column that are either significantly different (when the letters are different) or not (when the letters are the same) using DMRT at $P < 0.05$

Table 2. Correlation analysis of recovery percentage and temperature (°C)

Month	x= temperature (°C)	y= recovery %	(x- \bar{x})	(y- \bar{y})	k=(x- \bar{x}) (y- \bar{y})	m=(x- \bar{x}) ²	n=(y- \bar{y}) ²
March	23.3	19.84	-4.02	0.65	-2.61	16.15	0.42
April	26.17	17.91	-1.15	-1.28	1.47	1.32	1.64
May	28.4	19.33	1.08	0.14	0.15	1.17	0.02
June	28.2	17.68	0.88	-1.51	-1.33	0.78	2.28
July	29.1	19.73	1.78	0.54	0.96	3.17	0.29
August	29.25	19.27	1.93	0.08	0.15	3.73	0.01
September	29.25	18.27	1.93	-0.92	-1.78	3.73	0.85
October	27.35	19.46	0.03	0.27	0.01	0.00	0.07
November	24.85	21.22	-2.47	2.03	-5.01	6.10	4.12
	$\bar{x} = 27.32$	$\bar{y} = 19.19$	$\Sigma = 0$	$\Sigma = 0$	$\Sigma = -7.98$	$\Sigma = 36.14$	$\Sigma = 9.7$

$$\text{Correlation Coefficient } (r) = \frac{\Sigma k}{\sqrt{\Sigma mn}} = \frac{-7.98}{\sqrt{(36.14 \times 9.7)}} = -0.43$$

3.2 Relationship between Recovery Percentage and Some Weather Parameters

Green tea recovery percentage was different in different month (Table 1). In every month weather condition was different due to difference in temperature (°C), rainfall (mm), relative humidity (%), sunshine hour etc. In this section, the degree and nature of relationship between recovery percentage and these four weather parameters were assessed and calculated.

3.2.1 Relationship between recovery percentage and temperature (°C)

The relationship between temperature (°C) and recovery percentage of green tea was determined by correlation analysis with the null hypothesis (Ho) that there was no statistically significant correlation between these two parameters. Denoting 'x' as monthly average temperature (°C) and 'y' as monthly recovery percentage (%), correlation coefficient was calculated by correlation analysis (Table 2).

The correlation coefficient (r) was -0.43 explaining as a moderate negative correlation (nb. the nearer the value is to zero, the weaker the relationship) between these two parameters was found. But The P-Value was 0.2523 (Table 3) which was greater than 0.05, hence null

hypothesis (Ho) was accepted. Thus an insignificant moderate negative relation was found between recovery percentage and monthly average temperature (°C). Negative correlation was also found between crop growth and temperature in different crops. For example, increase of temperature causes the decrease of growth, yield and dry-matter production of rice [18] as well as wheat production [19].

3.2.2 Relationship between recovery percentage and rainfall (mm)

The relationship between rainfall (mm) and recovery percentage of green tea was analyzed through correlation analysis with the null hypothesis (Ho) as there was no statistically significant correlation between rainfall (mm) and recovery percentage. Denoting 'x' as monthly rainfall (mm) and 'y' as monthly recovery percentage (%), correlation coefficient was calculated (Table 4) by correlation analysis.

The correlation coefficient (r) was -0.942. So, there was a strong negative correlation, which means that high 'x' (=rainfall) scores go with low 'y' (= recovery percentage) variable scores (and vice versa). For this reason, recovery percentage (Table 4) was higher (21.22%) in the month of November'17 with less rainfall (12 mm) and recovery percentage was lower (17.68%) in the month of June'17 with higher rainfall (895

Table 3. ANOVA table of recovery percentage and temperature (°C)

ANOVA					
	df	SS	MS	F	P-Value
Regression	1	6.5733	6.5733	1.5560	0.2523
Residual	7	29.5703	4.2243		
Total	8	36.1436			

Table 4. Correlation analysis of recovery percentage and rainfall (mm)

Month	x= rainfall (mm)	y= recovery %	(x- \bar{x})	(y- \bar{y})	k= (x- \bar{x})(y- \bar{y})	m=(x- \bar{x}) ²	n= (y- \bar{y}) ²
March	237	19.84	-165.78	0.65	-107.76	27483.01	0.42
April	641	17.91	238.22	-1.28	-304.92	56748.77	1.64
May	353	19.33	-49.78	0.14	-6.97	2478.05	0.02
June	895	17.68	492.22	-1.51	-743.25	242280.53	2.28
July	237	19.73	-165.78	0.54	-89.52	27483.01	0.29
August	452	19.27	49.22	0.08	3.98	2422.61	0.01
September	463	18.27	60.22	-0.92	-55.4	3626.45	0.85
October	335	19.46	-67.78	0.27	-18.3	4594.13	0.07
November	12	21.22	-390.78	2.03	-793.28	152709.01	4.12
	$\bar{x}=402.78$	$\bar{y}=19.19$	$\Sigma=0$	$\Sigma=0$	$\Sigma=-2115.42$	$\Sigma=519825.57$	$\Sigma=9.7$

$$\text{Correlation Coefficient } (r) = \frac{\Sigma k}{\sqrt{\Sigma m \Sigma n}} = \frac{-2115.42}{\sqrt{(519825.57 \times 9.7)}} = -0.942$$

mm). The P-Value was 0.000146 (Table 5) which was significant at $p < 0.05$, hence, the null hypothesis (H_0) was rejected, can be explained as rainfall (mm) had statistically significant relation on recovery percentage. The R Square Value was 0.8876 (Table 6), that means 88.76% of recovery percentage can be explained by rainfall.

Rainfall also has a strong relation maize yield [20] and rainfall variability parameters could be used to develop yield forecast models for millet and sorghum in the Sudan Savanna ecological zone of Nigeria [21]. To predict the response of recovery percentage against rainfall, the linear regression graph was made (Fig. 1) and regression equation was $y = (-0.0041x) + 20.829$.

3.2.3 Relationship between recovery percentage and relative humidity (%)

To assess the relationship between relative humidity (%) and recovery percentage of green

tea, correlation analysis was done with the null hypothesis (H_0) as there was no statistically significant correlation between relative humidity (%) and recovery percentage. Denoting 'x' as monthly relative humidity (%) and 'y' as monthly recovery percentage (%), correlation coefficient was determined by correlation analysis (Table 7).

The P-Value was 0.322 (Table 8) which was greater than 0.05, hence null hypothesis (H_0) was accepted and correlation coefficient (r) was -0.37. So it can be concluded that an insignificant moderate negative relation was observed between recovery percentage and relative humidity (%). Relative humidity has different types of influence on growth of different crops. For example, in case of rice, high humidity during the light period was significantly more effective than dark period for the growth [22]. Again a strong influence of relative humidity was also found on growth of sweet potato [23].

Table 5. ANOVA table of recovery percentage and rainfall (mm)

ANOVA					
	df	SS	MS	F	P-Value
Regression	1	461419.3	461419.3	55.301	0.000146
Residual	7	58406.27	8343.754		
Total	8	519825.6			

Table 6. Regression statistics of recovery percentage and rainfall (mm)

Regression Statistics	
R Square	0.8876
Adjusted R Square	0.8715
Standard Error	91.344

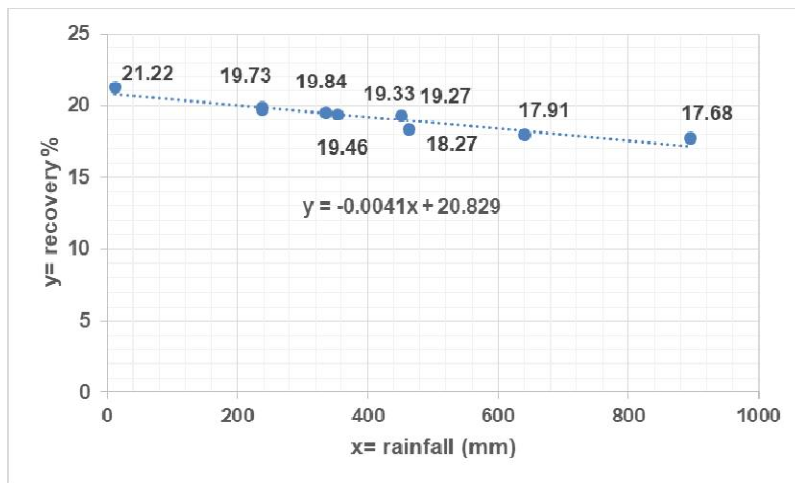


Fig. 1. Linear regression graph of y=recovery percentage against x= rainfall

Table 7. Correlation analysis of recovery percentage and relative humidity (%)

Month	x= humidity (%)	y= recovery %	(x- \bar{x})	(y- \bar{y})	k= (x- \bar{x}) (y- \bar{y})	m=(x- \bar{x}) ²	n= (y- \bar{y}) ²
March	66.3	19.84	-11.87	0.65	-7.71	140.89	0.42
April	75.7	17.91	-2.46	-1.28	3.15	6.05	1.63
May	74	19.33	-4.16	0.14	-0.58	17.31	0.02
June	83.3	17.68	5.13	-1.51	-7.75	26.32	2.28
July	81.6	19.73	3.43	0.54	1.85	11.76	0.29
August	80.8	19.27	2.63	0.08	0.21	6.92	0.01
September	83.6	18.27	5.43	-0.92	-4.99	29.48	0.84
October	81.9	19.46	3.73	0.27	1.01	13.91	0.07
November	76.3	21.22	-1.86	2.03	-3.78	3.46	4.12
	$\bar{x}=78.17$	$\bar{y}=19.19$	$\Sigma=0$	$\Sigma=0$	$\Sigma=-18.61$	$\Sigma=256.10$	$\Sigma=9.7$

Correlation Coefficient (r) = $\frac{\Sigma k}{\sqrt{\Sigma mn}} = \frac{-18.61}{\sqrt{(256.10 \times 9.7)}} = -0.37$

Table 8. ANOVA table of recovery percentage and relative humidity (%)

ANOVA					
	df	SS	MS	F	P-Value
Regression	1	35.693	35.693	1.132	0.322
Residual	7	220.586	31.512		
Total	8	256.28			

3.2.4 Relationship between recovery percentage and sunshine hour

The relationship between recovery percentage and sunshine hour was determined by correlation analysis with a null hypothesis (Ho) indicated as

insignificant relationship between recovery percentage and sunshine hour. Denoting 'x' as monthly sunshine hour and 'y' as monthly recovery percentage (%), correlation coefficient was determined by correlation analysis (Table 9).

Table 9. Correlation analysis of recovery percentage and sunshine hour

Month	x= sunshine hour	y= recovery %	(x- \bar{x})	(y- \bar{y})	k=(x- \bar{x}) (y- \bar{y})	m=(x- \bar{x}) ²	n=(y- \bar{y}) ²
March	5.6	19.84	0.56	0.65	0.36	0.31	0.42
April	5.5	17.91	0.45	-1.28	-0.58	0.2	1.64
May	6.3	19.33	1.25	0.14	0.18	1.56	0.02
June	3.3	17.68	-1.74	-1.51	2.63	3.01	2.28
July	3.3	19.73	-1.74	0.54	-0.93	3.03	0.29
August	3.9	19.27	-1.14	0.08	-0.09	1.29	0.01
September	3.8	18.27	-1.24	-0.92	1.14	1.54	0.85
October	5.9	19.46	0.85	0.27	0.23	0.72	0.07
November	7.8	21.22	2.75	2.03	5.58	7.56	4.12
	$\bar{x}=5.04$	$\bar{y}=19.19$	$\Sigma=0$	$\Sigma=0$	$\Sigma=8.52$	$\Sigma=19.22$	$\Sigma=9.7$

Correlation Coefficient (r) = $\frac{\Sigma k}{\sqrt{\Sigma mn}} = \frac{8.52}{\sqrt{(19.22 \times 9.7)}} = 0.62$

Table 10. ANOVA table of recovery percentage and sunshine hour

ANOVA					
	df	SS	MS	F	P-Value
Regression	1	7.4915	7.4915	4.4176	0.07367
Residual	7	11.8707	1.6958		
Total	8	19.3622			

The correlation coefficient (r) was 0.62 which indicated that there was a considerable high positive correlation. That means recovery percentage was increased with the increase of sunshine hour and vice versa. But the P-Value was 0.07367 (Table 10) and greater at $p > 0.05$, hence the relationship was not significant as null hypothesis was retained. Hours of sunlight influences significantly the duration of the vegetation period of different field crops such as, safflower, cotton, and potato [24]. Again, seasonal productivity of Aman rice was mostly and inversely correlated with sunshine hour [25].

4. CONCLUSION

On the basis of above study it can be concluded that in every stage of green tea manufacturing process weight of green leaves was gradually decreased except steaming stage, where weight was slightly increased due to accumulation of moisture to the green leaves. In case of BTRI recommended green tea manufacturing process the average recovery percentage (%) was 19.19% with an average moisture content of 3.72%. Green tea recovery percentage (%) was different with the different weather conditions in different months. Among four weather parameters, mainly rainfall was responsible for the variation of recovery percentages at different months. The relationship between rainfall (mm) and recovery percentage was strong negative and significant. To predict the response of recovery percentage against rainfall, the linear regression equation was $y = (-0.0041x) + 20.829$. On the other hand, the effect of other weather parameters (such as: temperature, relative humidity and sunshine hour) was insignificant to recovery percentage.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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