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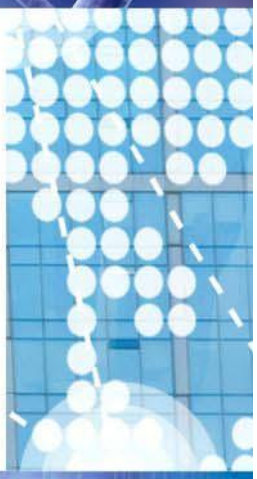

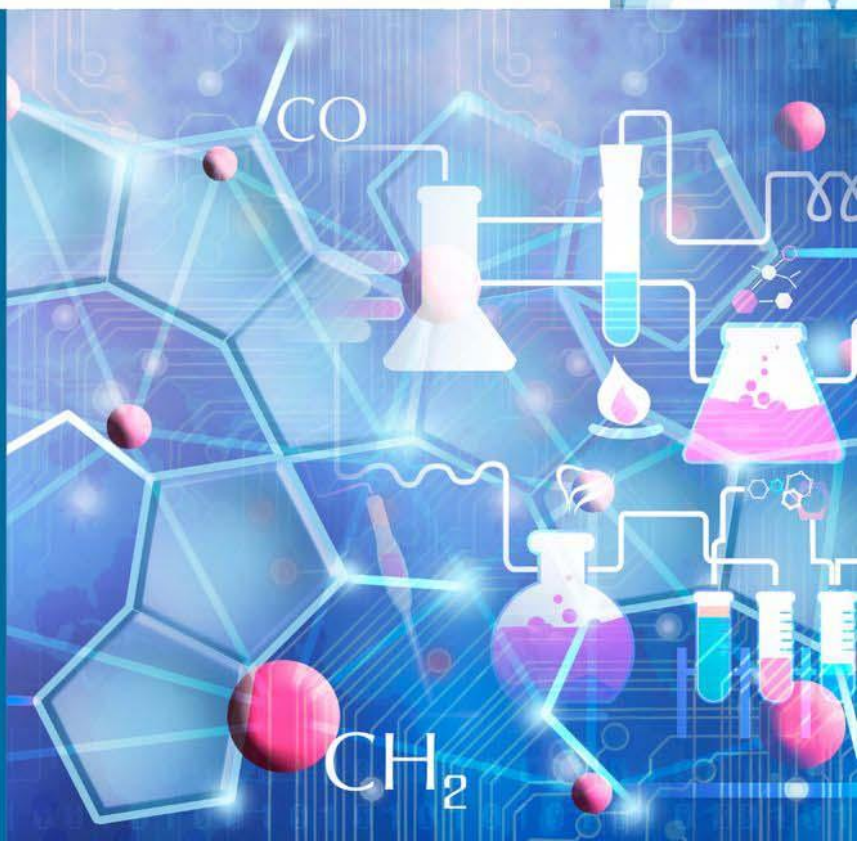

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A Case Study on the Factors Contributing to Unsatisfactory Academic Performance at Secondary Level: Evidence from Rajuk Uttara Model College, Bangladesh

Nelufa Aktar[a], , Mohd. Rezaul Haque[a] *, Mohammad Ibrahim Auli Ullah[a], Md. Matlubur Rahman[a], Md. Enamul Islam[a], Mohammad Faizur Rahman [b]

[a]*Rajuk Uttara Model College (RUMC), Uttara Model Town, Dhaka-1230, Bangladesh*
[b]*Ahsanullah University of Science and Technology (AUST), Dhaka-1208, Bangladesh*

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ABSTRACT

This case study explores the underlying factors contributing to unsatisfactory academic performance among Business Studies students at Rajuk Uttara Model College (RUMC), one of the most prestigious higher secondary education institutions of Bangladesh. Despite its strong academic reputation, particularly in the Science stream, RUMC faces a consistent disparity in results between Science and Business Studies students in the Secondary School Certificate (SSC) examinations. Employing a quantitative research approach, data were collected from 532 students through a structured questionnaire. The collected data were analyzed using SPSS (version 25) employing descriptive statistics, correlation, and regression analysis to identify significant variables impacting academic outcomes. The findings reveal a complex interplay of academic, socioeconomic, institutional and psychological factors. The results indicate a significant correlation among visiting one's native home, family income, and time management during examinations. The findings demonstrate systemic issues, such as a 69% decrease in the chance of receiving a good SSC score for each unit drop in the perception of class efficacy. Moreover, students from higher-income families who experience greater stress or lack self-motivation are approximately 71% less likely to achieve good SSC results under time pressure during written examinations compared to students from lower-income backgrounds. Besides providing evidence-based insights into the academic underperformance of RUMC, this study holds wider implications for pedagogical advancements and policy changes at other similar institutions in Bangladesh.

1. Introduction

Academic performance at the secondary level serves as a crucial determinant in shaping students' future educational and professional trajectories. In Bangladesh, particularly in prestigious institutions like Rajuk Uttara Model College, a top-tier education institution, the expectation for academic excellence is high. Despite the prominence of a reputed institution and resource availability, there exists a growing concern over unsatisfactory academic performance among a segment of students, namely Business Studies students, warranting an in-depth exploration of the underlying causes. Existing literature identifies a complex interplay of multitude of factors influencing students' academic achievements, including socio-economic background, parental education and involvement, institutional environment, teaching methodology, institutional support, and student motivation (Farooq et al., 2011; Hijazi & Naqvi, 2006), (Naqvi, 2006). Farooq et al. (2011) underscore that academic performance is influenced not only by students' abilities but also by family income, parental involvement, and school infrastructure. Similarly, Hijazi and Naqvi (2006) highlight the role of psychological, economic, and environmental variables in shaping students' academic outcomes in private institutions (Naqvi, 2006). A recurring theme in studies across South Asia and beyond is the impact of socio-economic status (SES). Researchers consistently find that students from lower SES backgrounds face challenges such as limited access to educational resources, poor nutrition, and insufficient academic support at home, which negatively affect

***Corresponding Author:** Mohd. Rezaul Haque
Email Address: reza_rumc@yahoo.com

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academic performance (Esen & Adıgüzel, 2023; Islam & Khan, 2017; Razzaq et al., 2024). These findings suggest that both personal and contextual variables work interactively to affect students' success.

In the context of Bangladesh, multiple researchers have attempted to assess these variables through empirical evidence. Alam and Islam (2022) revealed that both economic instability (financial hardship) and poor institutional practices (lack of academic support) contribute significantly to students' academic struggles in public universities — a trend often rooted in earlier educational stages (Markos et al., 2022). Similarly, Ahmmed and Salim (2018) found that inadequate academic support services, low teacher engagement, and lack of structured feedback mechanisms in private universities also hinder students' learning progression (Rahman et al., 2022). These challenges are not exclusive to tertiary education. At the secondary level where students are transitioning to adulthood and facing national public examinations, such issues may manifest even more intensely.

The method of instruction also plays a pivotal role. Traditional rote-learning practices prevalent in many Bangladeshi schools have long been critiqued for failing to foster critical thinking and deep understanding. In contrast, recent experimental studies advocate for more interactive approaches, like design thinking have demonstrated a more positive influence on students' learning compared to traditional rote-learning methods, offering promising alternatives for improving student performance (Ekvitayavetchanukul et al., 2025).

Furthermore, psychological and gender-based factors have been shown to influence academic performance. Parajuli and Thapa (2017) highlight significant gender differences in academic outcomes, often shaped by sociocultural expectations and support systems. Additionally, Kapur (2018) emphasizes the role of students' attitudes, study habits, and motivation levels as critical contributors to success at the secondary level. While existing literature offers significant insights, there remains a gap in understanding how these multilayered factors play out within individual institutions, particularly those considered academically elite. This study aims:

- To address the contextual and institutional factors leading to unsatisfactory academic performance of Business Studies students at the secondary level.
- To identify socio-demographic factors contributing to lower academic achievement among Business Studies group students.

Thus, this case study aims to offer evidence-based recommendations for Rajuk Uttara Model College and other similar institutions that are facing analogous challenges by examining the dimensions in a specific and high-performing educational context.

2. Methodology

Study Design and Setting

This study followed a quantitative, cross-sectional case study design to examine the factors contributing to unsatisfactory academic performance of Business Studies group students at the secondary level. The research was conducted at Rajuk Uttara Model College, a renowned educational institution in Dhaka, Bangladesh.

Study Population and Sample Size

The target population consisted of higher secondary level students from both the Science and Business Studies groups, totaling 1490 students.

To determine the minimum required sample size, Cochran's formula was used, which is appropriate for large and finite populations. The formula is as follows:

$$n_0 = \frac{z^2 \times p\,(1-p)}{e^2}$$

Where:

- Z = 1.96 (Z-value for 95% confidence level)
- p = 0.5 (estimated proportion for maximum variability)
- e = 0.05 (margin of error)

$$n_0 = \frac{(1.96)^2 \times 0.5 \times (1-0.5)}{(0.05)^2} = 384.16$$

Since the population is finite (N=1490), the sample size was adjusted using the finite population correction formula:

$$n = \frac{n_0}{1 + \frac{n_0 - 1}{N}}$$

$$n = \frac{384}{1 + \frac{383}{1490}} = 306$$

Therefore, the minimum required sample size was 306 students.

However, to enhance the precision and robustness of the analysis, data were collected from a total of 532 students, exceeding the minimum requirement.

Sampling Technique

A simple random sampling technique was applied to ensure that every student in the population had an equal and independent chance of selection. This method reduced sampling bias and improved the representativeness of the sample.

Sampling Unit

Individual student of Science and Business studies of RUMC is the unit of study.

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Data Collection Procedure

Data were collected through a structured and pre-tested questionnaire. The instrument was designed to gather relevant information on students' demographic characteristics, academic records, parental involvement, stress levels, time management and institutional characteristics. Ethical practices such as informed consent, voluntary participation, and confidentiality were strictly maintained.

Data Analysis Tools and Techniques

The collected data were analyzed using IBM SPSS Statistics software - version 25. The following statistical techniques were employed:

- **Descriptive Statistics**: To summarize demographic variables and academic performance distributions.
- **Correlation Analysis**: Pearson correlation was used to assess the relationships between academic performance and influencing factors.
- **Regression Analysis**: To identify the key predictors of unsatisfactory academic performance and evaluate their impact.

3. Results and Discussion

A total of 532 participants were included in this study. The gender distribution was nearly equal, with 262 males (49.2%) and 270 females (50.8%). Regarding educational background, a majority (62.6%) of the students were from the Science group while the remaining 37.4% was from the Business Studies group.

A higher percentage, 61.5% (n = 327), said they did not visit their home place on short holidays, whereas 38.5% (n = 205) mentioned doing so. Their opinions reflect the growing urbanization and diminished ties to rural or ancestral locations that have been seen in numerous Bangladeshi regions (Afsar, 2003). During the holidays, students who stay in cities could have easier access to academic resources like private tutoring or library services, which could affect their academic achievement. However, as regular family visits are proven to improve teenagers' mental health and emotional stability, losing ties to one's birthplace may also result in a decline in emotional well-being (Sadownik, 2023).

Table 1: Demographic Characteristics of Participants:

Demographic Characteristics of Participants		
		Frequency (%)
Gender	Male	262 (49.2)
	Female	270 (50.8)
SSC Group	Science	333 (62.6)
	Business Studies	199 (37.4)
Visiting native home during short vacation	Yes	205 (38.5)
	No	327 (61.5)
Family income (per month)	Less than 30k	45 (8.5)
	30k-50k	183 (34.4)
	>50k	304 (57.1)
Father's occupation	Businessman	184 (34.6)
	Government employee	88 (16.5)
	Others	260 (48.9)
Mother's occupation	Housewife	440 (82.7)
	Government employee	38 (7.1)
	Others	54 (10.2)
Results in SSC Examination (GPA)	Good(GPA-5)	438 (82.3)
	Average (Less than GPA-5)	94 (17.7)

In terms of monthly family income, over half of the participants (57.1%) came from families earning more than 50,000 BDT, while 34.4% reported a family income between 30,000 and 50,000 BDT, and 8.5% reported earning less than 30,000 BDT per month. Because of the availability of educational resources, stable home conditions, and parental support, previous studies have consistently demonstrated a favorable association between higher family income and improved academic achievements (Selvitopu & Kaya, 2021). However, economic variety is highlighted by the sizeable percentage (34.4%) from middle-income and 8.5% from low-income households. Low-income students frequently encounter obstacles including restricted access to digital learning platforms or private coaching, which can affect their academic performance and happiness (Glewwe & Kremer, 2006).

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Regarding father's occupation, 34.6% were businessmen, 16.5% were government employees, and 48.9% were engaged in other occupations. For the mother's occupation, the vast majority were housewives (82.7%).Long-standing cultural traditions in South Asian nations, where women are expected to run the home and males are usually the main breadwinners, are reflected in this trend (Ahsan et al., 2019). These gendered employment positions can impact pupils' educational objectives. Children of working mothers, particularly those in professional occupations requiring a high level of education, have been observed to have more academic ambition and career orientation (Gaikwad & Pandey, 2025). Nonetheless, the preponderance of mothers who are homemakers may also suggest that more time is spent monitoring children's academic progress and providing emotional support, particularly for younger pupils. Academic performance in the Secondary School Certificate (SSC) examination was also reported. A significant majority of the participants (82.3%) achieved a GPA of 5 (considered 'Good'), whereas the remaining 17.7% scored below GPA-5 and were categorized as having 'Average' results. This is encouraging and might be related to many respondents' greater socioeconomic level and supportive familial environments. Previous research has shown that academic motivation, household wealth, and parental participation are all powerful indicators of academic achievement in secondary school (Fan & Chen, 2001), (Akhter & Siddiky, 2024). The remaining 17.7% who had a GPA below 5 can be the result of personal struggles like stress or a lack of drive, disparities in the quality of the schools, or unequal access to resources.

3.1 Characteristics of Participants' Opinions

Table 2: **Characteristics of Participants' Opinions**

Variables		Frequency	%
How do you rate the teaching quality of your class?	Excellent	49	9.2
	Good	228	42.2
	Average	190	35.7
	Poor	65	12.9
Do students attend classes regularly?	Most students do	339	63.7
	Some students do	165	31.0
	Very few students do	28	5.3
Are the classes conducted by the teacher effective?	Always	157	29.5
	Often	217	40.8
	Rarely	141	26.5
	Never	17	3.2
I think my group choice was right during class IX admission.	Strongly agree	254	47.7
	Agree	178	33.5
	Neutral	67	12.6
	Disagree	13	2.4
	Strongly disagree	20	3.8
I think teachers in my group provide proper guidance for exam preparation.	Strongly agree	61	11.5
	Agree	217	40.8
	Neutral	168	31.6
	Disagree	47	8.8
	Strongly disagree	39	7.3
I think converting theory subjects to practical subjects can improve result.	Strongly agree	165	31
	Agree	196	36.8
	Neutral	114	21.4
	Disagree	32	6.0
	Strongly disagree	25	4.7
I think converting theoretical subjects examinations to CQs and MCQs can improve the results.	Strongly agree	94	17.7
	Agree	199	37.4
	Neutral	188	35.4
	Disagree	25	4.7
	Strongly disagree	26	4.8

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I think students of Business Studies get admitted with poorer results than those of Science students.	Strongly agree	123	23.1
	Agree	171	32.1
	Neutral	143	26.9
	Disagree	60	11.4
	Strongly disagree	35	6.5
The Business Studies syllabus is more difficult than that of the Science group.	Yes	84	15.8
	No	448	84.6
Business Studies has fewer practical subjects compared to the Science group, and more practical subjects often lead to better results.	Yes	377	70.9
	No	155	29.1
Business Studies students get less time per question in the written examinations while Science students get more time.	Yes	416	78.2
	No	116	21.8
Business Studies students get less time to complete all questions within the allocated time.	Yes	339	63.7
	No	193	36.3

The results of the study show that secondary students have differing opinions about the quality of instruction and the structure of the classroom. The majority thought their lessons were frequently successful (40.8%) and evaluated their instruction as good (42.2%). The majority of students concurred that teachers gave adequate advice for test preparation and felt secure about the group they were admitted to. Nonetheless, a lot of students think that employing creative question (CQ) and multiple-choice question (MCQ)-based tests or turning theoretical courses into practical forms might enhance academic achievement. Notably, a sizeable percentage of respondents voiced worries that students studying Business Studies are at a disadvantage when compared to those studying science. These concerns include perceived lower admission criteria, fewer practical courses, and stricter test schedules. These observations imply that in order to advance equity and improve learning outcomes, curriculum modifications and teaching method reforms are required.

Reforms to the present evaluation systems were preferred by a sizeable portion of pupils. In particular, they promoted the use of MCQs, CQs and hands-on techniques for theoretical teaching. In order to accommodate different learning styles and foster deeper knowledge, a variety of evaluation techniques and a trend towards more student-centered learning are being used globally in pedagogy (Black & Wiliam, 2009). While formative and diverse tests are thought to better enhance students' learning, traditional rote-based examinations are frequently criticized for not fostering critical thinking and application skills (Boud & Falchikov, 2006).

Concerns over structural disadvantages in comparison to their science counterparts were particularly raised by students in the Business Studies stream. Perceptions of tighter examination schedules, fewer possibilities for experiential or practical learning, and lower entrance criteria were among them. Disparities of this kind might impede motivation and success and even lead to feelings of academic inadequacy. This is consistent with earlier research on academic tracking and stream-based disparities, which found that students in non-science groups frequently had less access to academic opportunities and resources (Kim & Sunderman, 2005). These issues highlight how curricular frameworks need to be reviewed by Ministry of Education of Bangladesh in order to guarantee academic stream equity. All students must have equal access to high-quality instruction, impartial evaluation procedures, and chances for hands-on experience, regardless of their academic program, in order for education to be equitable (Rieckmann et al., 2017).

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3.2 Correlation

Table 3: Correlation Coefficient of Different Variables with Results in SSC Examination

Variables	Category	Results in SSC Examination		χ^2 value (p-value)
		Good (GPA-5)	Average (Less than GPA-5)	
Gender	Male	215	47	0.872
	Female	223	47	
Do you visit native home during short vacation?	Yes	168	37	0.001
	No	270	57	
Family income(monthly)	Less than 30k	35	10	0.027
	30k-50k	141	42	
	More than 50k	262	42	
Father's occupation	Businessman	142	42	0.005
	Public service	82	06	
	Others	214	46	
Mother's occupation	Housewife	357	83	0.410
	Public service	37	01	
	Others	44	10	
Monthly family income	< BDT 10,000	35	10	0.027
	BDT 10,000 – BDT 30,000	141	42	
	>BDT 30,000	262	42	
Rating teaching quality of teachers	Excellent	32	17	<0.001
	Good	172	56	
	Average	172	18	
	Poor	62	03	
Are the classes conducted by teachers effective?	Always	100	57	<0.001
	Often	186	31	
	Rarely	137	04	
	Never	15	02	
Business Studies students get less time per question in written examinations while Science students get more time.	Yes	331	85	<0.001
	No	107	09	
Business Studies students get less time to complete all questions within allocated time.	Yes	259	80	<0.001
	No	179	14	

This table employs the Chi-square (χ^2) test to examine the relationship between students' SSC scores (classified as 'Good' if their GPA is 5 and 'Average' if their GPA is less than 5) and other academic and demographic parameters. The variables and SSC results are statistically significantly correlated when the p-value < 0.05. We can observe both positive and negative correlations here. Not all of them have a strong correlation, while some have a modest one. Visit to one's native place, family income, the father's line of work, opinions on the caliber and efficacy of instruction, and time management during tests were among the factors that were shown to have a statistically significant correlation with SSC results.

This supports the body of research indicating that instructional clarity and teacher quality are critical for academic performance ("Teacher Quality and Student Achievement: A Review of State Policy Evidence," 1999). Strong academic performance is predicted by improved conceptual understanding, motivation, and student engagement, all of which are enhanced by high-quality instruction. Additionally, there was a substantial association between SSC results and time management in

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the examination. The likelihood of receiving a top mark was reduced for students who could not finish the test in the allotted time. This is consistent with research by Putwain (2009), (Högberg, 2021), who pointed out that performance is frequently affected by examination pressure and inefficient time management, especially in high-stakes testing settings like those in South Asia.

The findings show a positive correlation between SSC performance and father's employment and family income. Pupils who come from wealthier families or whose fathers hold steady jobs typically do better academically. This echoes more general socioeconomic theories that assert that access to learning resources, tutoring, and a nurturing family environment are all made possible by financial means (Sirin, 2005), (Musset et al., 2012). The occupation of mothers did not exhibit a statistically significant correlation which is interesting. This could be a reflection of the region's traditional family arrangements, where fathers are frequently the main providers and have a more direct contribution in how much money is spent on education, but mothers jobs might not have a direct impact on kids' academic performance or access to resources (Jeynes, 2014).
Nevertheless, there was no obvious association between the mother's gender and her line of employment. There was no statistically significant difference in SSC performance depending on gender, which is in contrast to other previous research. Although previous studies have discovered gender differences in the performance of particular subjects (Savva & Anastasiou, 2024), our results imply that gender could not be a significant factor when taking into account total GPA.

3.3 Logistic Regression Analysis and Their Coefficients

Table 4. Logistic Regression Analysis and Their Coefficients

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Do you visit native home during short vacation?	.309	.259	1.424	1	.233	1.361
	Family income (per month)	-.568	.191	8.843	1	.003	.567
	Father's occupation	-.067	.137	.239	1	.625	.935
	Are the classes conducted by the teachers effective?	-1.172	.187	39.304	1	<.001	.310
	Business Studies students get less time per question in the written examination while Science students get more time.	-.318	.444	.515	1	.473	.727
	Business Studies students get less time to complete all questions within the allocated time.	-1.220	.369	10.949	1	<.001	.295
	Constant	.448	.376	1.417	1	.234	1.565

This logistic regression model examines the relationship between a number of independent factors and the likelihood of receiving a good score (GPA-5) on the SSC examination. According to the coefficient for "Are the classes conducted by the teachers effective?" a one-unit drop in the perception of class effectiveness is linked to a 69% drop in the chances of getting a good score on the SSC examination, while keeping all other factors equal, such as visiting one's native home, family income, the father's occupation, and time management during exams. Students who do not find the classes beneficial are only 31% more likely to receive a GPA-5 than those who find the classes always effective, as indicated by Exp (−1.172) = 0.310.

This is consistent with earlier studies that highlight how crucial high-quality instruction is in influencing student outcomes ("Teacher Quality and Student Achievement," 2000). Students who get effective classroom teaching are more motivated, grasp, and retain information better, all of which have a direct impact on exam

performance (Seidel & Shavelson, 2007). According to the current research, even in cases when other factors like family background and time management are advantageous, students who do not gain from classroom teaching are at a significant disadvantage.

Similarly, the variable "Business Studies students get less time to complete all questions within the allocated time" has a statistically significant negative coefficient of −1.220. This means that, after adjusting for other variables, students who experience time pressure during the written exam have a roughly 71% lower chance of receiving a good SSC result. According to Exp (−1.220) = 0.295, students who fail to finish the test on time have a 29.5% lower chance of receiving a GPA of 5 than those who do it in the allotted time.

This result is consistent with other research showing that time limitation can increase test anxiety and impair cognitive function under duress (Putwain, 2009). Sufficient time is crucial, particularly for descriptive and analytical courses where students are required to provide detailed explanations of their responses. Students who struggle with time management or who are disadvantaged by strict time constraints could not

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perform their best on tests, leading to less than ideal results.

However, the variable 'Family income (per month)' exhibits a significant negative correlation with SSC performance, with Exp(−0.568) = 0.567. This suggests that, when all other factors are held constant, the odds of scoring GPA-5 drop by roughly 43% for every unit increase in family income category. In contrast to their friends from lower-income homes, pupils from higher-income households are under more pressure or less self-motivated, according to this surprising discovery. According to earlier research conducted in Bangladesh, a lack of resources and guidance is linked to low performance, and familial financial and attitudinal support are significant determinants of SSC achievement (Habib & Mawa, 2022). Our surprising discovery could be the result of changed expectations, pressure, or a lack of inner drive in rich households, even though having more money is normally protective.

The pie chart shows that just 39% of respondents take short vacations to their hometown, while the majority (61%) of respondents said they seldom take short vacations there.

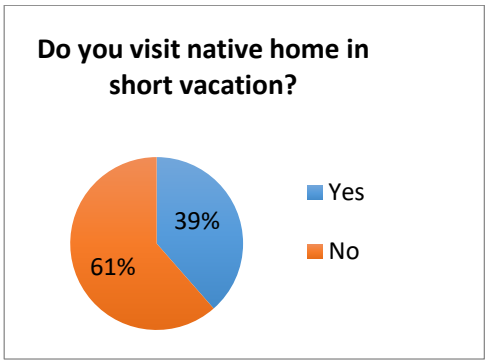

Figure 1: Pie chart

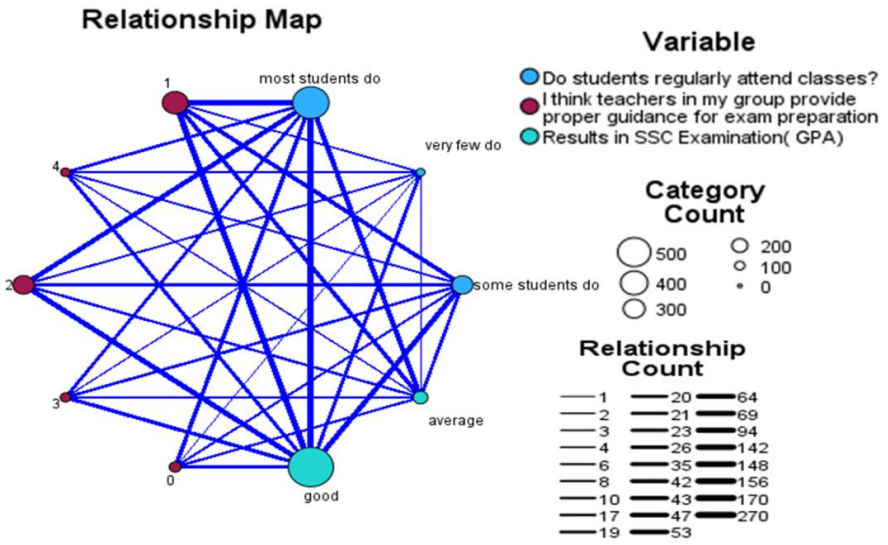

Figure 2: Relationship between attending classes regularly and result in SSC

The relationship map reveals that prior academic performance (SSC GPA), perceived teacher support, and class attendance are strongly correlated. Regular attendees who feel their teachers provide them with appropriate guidance are more likely to report higher SSC scores and give teaching quality higher ratings. The graphic emphasizes how important teacher support and attendance are in determining students' academic success.

Crucially, the connection map emphasizes how perceived teacher support and attendance interact. Students who see their teachers as encouraging and who attend lessons on a regular basis perform noticeably better academically. The self-determination hypothesis, which holds that meeting fundamental psychological needs including feeling competent, encouraged, and independent encourages intrinsic motivation and perseverance in learning, lends credence to this study (Deci & Ryan, 2000). Consistent attendance reinforces the learning process through involvement and reinforcement, while teacher support increases students' emotional stability in the classroom.

These results have lasting impacts for Bangladeshi secondary education. In addition to delivering the curriculum, efforts to boost academic achievement should also include building solid teacher-student bonds and promoting consistent attendance. To improve supportive teaching practices, school administrators might introduce mentoring programs or workshops for teacher development. Academic achievement can be supported by policies that address barriers to regular attendance, such as transportation or health issues, or that provide incentives for attendance.

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4. Conclusion

The case study meticulously investigated and identified manifold factors contributing to unsatisfactory academic performance among secondary level students of Rajuk Uttara Model College. The findings reveal that several key determinants like visiting one's native home, family income, and time constraint during examinations have emerged as significant impediments to optimal student achievement. Addressing these challenges necessitates a holistic and multi-pronged approach involving collaborative actions from parents, teachers, education policymakers and students. Implementing training programs for teachers, fostering a supportive academic setting for students both at home and school along with more active engagement of parents in the academic journey of the students are essential. Psychological factors, including examination anxiety and a lack of intrinsic motivation further intensified the problem. Moreover, curricular reforms that balance theoretical and practical subjects might help reduce students' stress and enhance learning outcomes. Unsatisfactory academic performance at the secondary level at RUMC is not attributable to a single cause but rather a complex interplay of academic, socioeconomic, institutional and psychological factors. To further understand the intricate dynamics affecting student performance, future research could expand the scope of this study by including multiple institutions. Such initiatives would contribute to creating more effective and inclusive educational policies in Bangladesh.

5. Recommendations

Based on the findings of the study, several academic reforms are recommended to address the issues causing unsatisfactory academic performance at the secondary level in the Business Studies stream at Rajuk Uttara Model College:

1. Curriculum Adjustment for Subject Balance:
   The inclusion of more practical-oriented courses in place of excessive theoretical subjects is advocated. This adjustment can align the Business Studies curriculum more closely with the cognitive talents of the students, who may perform better in practical-based examinations rather than theory-based assessments.
2. Increase the Number of Multiple Choice Questions (MCQs):

   The number of multiple-choice questions in each subject may be increased in order to promote greater syllabus coverage and enhance objective evaluation. This approach can improve students' conceptual understanding and they can better prepare for more difficult competitive tests.
3. Introduce More Practical Subjects for Skill Development:
   Whereas the inclusion of practical subjects is suggested, theoretical subjects should not be entirely excluded. Instead, new practical subjects relevant to the Business Studies domain may be added introduced to promote real-life application skills and boost student engagement.
4. Reduce the Number of Broad Questions from 7 to 5:
   In alignment with the Science stream's examination format, reducing the number of descriptive questions from seven to five can lessen students' cognitive burden during examinations and can help students concentrate more intently on selected topics. This change might help in improving time management during evaluations and reduce examination-related stress.

Implementation of these recommendations can potentially create a more equitable academic environment across different streams and significantly enhance students' academic performance at the secondary level.

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Optimization of cultural conditions of lipase producing bacteria isolated from organic waste

Lovely Aktar and Mihir Lal Saha*
Department of Botany, University of Dhaka, Dhaka-1000, Bangladesh.

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ABSTRACT

This study aims to screen out the potential lipase producing bacteria and optimize various culture settings in order to maximize the production of lipase enzyme. From organic waste, a total of 29 lipase positive bacteria were isolated. *Bacillus subtilis* 20B was identified as having potential among them. The isolate produced lipase at an optimal level of 17.28±0.75 U/ml with 0.5% NaCl. The isolate produced a higher amount of lipase (37.39±0.67 U/ml) when it was cultivated in medium supplemented with 1.5% starch as a carbon source. However, when 1.5% yeast extract was utilized as an organic nitrogen source, it climbed to 25.17±0.67 U/ml and when 1.5% ammonium chloride was supplied as an inorganic nitrogen source, lipase production rose to 17.22±0.51 U/ml. Following substrate concentration adjustment, 1% olive oil concentration showed the highest activity (11.72±0.25 U/ml). Nutrient Broth (NB) medium was found to be better basal medium for lipase production with maximum activity of 16.28±0.42 U/ml. After 84 h of incubation, the isolate grew at its fastest rate (6.9×10^7cfu/ml), while the number of cells declined during this period. *B. subtilis* produced the most lipase during the exponential growth phase, which lasted 36 h. The current study provides valuable insights into the production of lipase by *B. subtilis* 20B, which could be a viable bacterial source of lipase for future research on treating of lipid-rich wastewater and other applications.

1. Introduction

All synthetic and degradative reactions of living things are catalyzed by enzymes, which are extremely effective biological catalysts. Since its first discovery in the second half of the nineteenth century, enzymes have become much more widely used in a variety of industries (Jamilu et al., 2022).

A class of hydrolytic enzymes known as lipase (triacylglycerol acylhydrolases; EC 3.1.1.3) catalyzes the hydrolysis of triacylglycerol to glycerol and free fatty acids (Gupta et al., 2004). Many lipases are used extensively in the food, detergent, pharmaceutical, leather, cosmetic, textile, dairy, and even biodiesel sectors because of their capacity to carry out both hydrolytic and synthetic processes (Hasan et al., 2006 & Robles-Medina et al., 2009). Although lipases are extensively found in both plants and animals, the majority of lipases that are available commercially are often derived from microbes that generate a diverse range of extracellular lipase (Kexin et al., 2021).

One of the biggest challenges facing the industry was thought to be the cost of the lipase production process. As a result, a lot of work is being done to use wastes as raw materials for the production of lipase. Future biotechnologies will heavily rely on agricultural leftovers for the manufacturing of lipase and other value-added products, primarily because to their environmentally friendly lines and adaptability to both developed and developing nations (Yang et al., 2021).

Every living thing has lipases, which are necessary for their regular functioning. The application of microbial lipases has drawn a lot of interest in recent decades (Rozi et al., 2022). These microbes are potential sources of lipases (Fatima et al., 2021). Many microbial strains have been screened and characterized for their ability to produce enzymes, and microbial biotechnologists have recently turned their focus to the commercial application of lipase of microbial origin. The microorganisms most commonly employed to produce lipase include *Aspergillus niger*, *Penicillium* sp., *Candida rugosa*,

***Corresponding Author:** Mihir Lal Saha
Email Address: sahaml@du.ac.bd

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Rhizopus sp., *Bacillus* sp. and *Pseudomonas* sp. (Lakshmi & Anupudi, 2021; Rodriguez-Salarichs et al., 2021; Helal et. al., 2021). Numerous microorganisms from various bacterial, fungal, and yeast genera have been isolated and screened from various environmental settings and these are the potential source of lipases (Yuan et al., 2021 & Pang, 2021).

The optimization process is typically approached one variable at a time, and the media composition factors that are subject to variation include physicochemical factors (incubation time, temperature, pH, presence of lipid as inducer, cofactors, inhibitors) and various nutritional factors such as carbon and nitrogen sources (Adio et al., 2021). Consequently, the stimulatory effect of various media on lipase synthesis varies (Phukon, et al., 2020). Since most researchers only concentrate on pH and temperature of the enzyme optimization, it was also crucial to evaluate the impact of different circumstances on substrate specificity. Its effectiveness and efficiency may suffer greatly if the impact of other parameters on enzyme production are not examined. Thus, the present work was undertaken to screen indigenous bacteria from organic waste for lipolytic activity and optimize the effects of various cultural factors on lipase synthesis.

2. Methodology

Isolation of lipase producing bacteria

In order to isolate bacteria, soil containing organic waste was collected from Mirpur, Dhaka Metropolitan area, Bangladesh. At 37ºC for 48 h, bacteria were isolated using the serial dilution technique. On Nutrient Agar (NA) plates, bacterial isolates were repeatedly streaked after being chosen at random and purified. The cultures were kept for later use at 4ºC. For 48 h at 37ºC, pure cultures were cultivated on two lipid-based media Tributyrin agar (TBA) and Tween agar (TA), in order to detect bacterial lipolytic activity. The development of a clear zone in TBA plates and the degree of opaque zone surrounding the colonies in TA plates are indicators of the lipase activities of the isolates (Bueno et al., 2014).

Molecular identification

The isolated bacteria was molecularly identified by 16S rRNA gene sequencing. Using the universal primers, the 16S rRNA gene from the genomic DNA was amplified by PCR. Bacterial DNA was extracted using the heat-thaw technique and stored at -20°C (Salehi et al., 2005). Then, using a thermocycler, PCR amplification was carried out (Aktar et al., 2016). The NCBI-BLAST database (http://blast.ncbi.nlm.nih.gov/) and rRNA BLAST (http://bioinformatics.psb. ugent.be/cgi-bin/rRNA/blastform.cgi) programs were used to analyze the sequence produced by automated sequencing of PCR amplified DNA in order to identify potential similar organisms through alignment of homologous sequences (Kerbaury et al., 2011). A phylogenetic tree was created using the sequence found in the BLAST search. The BLASTN (nucleotide BLAST) sequence was retrieved in FASTA format, and the CLUSTAL OMEGA algorithm software was used to align numerous sequences in order to determine the relationship between each sequence. Neighbor joining (NJ), a distance-based phylogenetic analysis tool was used to create the tree.

Lipase production

To produce lipase, the procedure of submerged fermentation was used (Anbu et al., 2011). Tryptone Soy Broth (TSB) was utilized as the liquid culture medium and 1% olive oil was added as a substrate. In this experiment, 1% inoculum was added to 50 ml of TSB medium in a 100 ml Erlenmeyer flask. A rotary shaker (Daihan Labtech, England) was used to continuously shake the inoculated flasks at 150 rpm for 48 h while they were incubated at 37°C. Following aseptic sample removal, cell-free supernatant was extracted using centrifugation at 9,000 rpm for 20 min at 4ºC. To determine the lipolytic activity, the clear supernatant was collected and utilized as a source of crude enzyme.

Estimation of lipase activity

Lipase activity was estimated as stated by Marseno et al. (1998). About 2 ml of reaction mixture, which contains 60% (v/v) olive oil dissolved in iso-octane, were taken and placed in a screw-cap vial. The reaction was started by adding 20 µl of crude enzyme and running at 150 rpm for 30 min at 30ºC. The combination was then immersed in an ice bath for ten minutes to instantly cease the reaction. The reaction mixture, which contains 1800 µl of iso-octane and 400 µl of cupric acetate pyridine at pH 6.0, was mixed with around 200 µl of the aliquots. The top layer of the iso-octane fraction was pipetted and the amount of free fatty acid that dissolved in the iso-octane layer was measured spectrophotometrically by measuring the optical density at 715 nm. The amount of oleic acid that liberated as free fatty acid from olive oil by the bacterial lipase enzyme was measured in order to quantify lipase activity. This was estimated using a well-known oleic acid standard curve. The quantity of lipase enzyme that generated one µmole fatty acid per minute was considered to be one unit of lipase activity. In this investigation, every experiment was conducted in triplicate.

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Optimization of different cultural parameters on lipase production

Optimization of different cultural parameters such as NaCl, concentration of carbon source, organic and inorganic nitrogen source, substrate and medium were carried out (Kumar et al., 2012 & Veerapagu et al., 2013). In this case, 1% (v/v) olive oil was used as an inducer for lipase production.

Effects of NaCl on lipase production

Different NaCl concentrations (0.5, 1.0, 1.5, 2.0, and 2.5%) were added to the lipase production medium while maintaining the same levels of all other parameters in order to examine the effects of NaCl on lipase production. After being added to the medium, the bacterial isolate was cultured for 48 h at 37°C.

Optimization of concentration of better carbon and nitrogen sources

Better carbon and nitrogen sources which support maximum lipase production were added at 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0% (w/v) in the production medium. The inoculated lipase production medium was incubated for 48 h at 37ºC in order to optimize it.

Effects of substrate concentration on lipase production

Using various olive oil concentrations (0.5, 1.0, 1.5, 2.0, 2.5, and 3.0% v/v) in the medium, the effects of olive oil concentration on lipase activity were ascertained. For 48 h, the inoculated medium was incubated at 37ºC.

Effects of media on lipase production

Five distinct basal media *viz.* Nutrient Broth (NB), Luria Bartani (LB), Tributyrin Broth (TBB), Tween Broth (TB), and Tryptone Soya Broth (TSB) were investigated for lipase production., The inoculated media were incubated at 37ºC for 48 h.

Determination of bacterial growth

By counting bacterial colonies, the growth of bacteria was ascertained. Using the dilution plate technique, the number of bacteria was measured as colony forming unit (cfu/ml). Serially diluted 1 ml culture mixed with molten nutrient agar. For 24 h, the inoculated plates were incubated at 37°C. A colony counter was used to count the number of bacterial colonies that had grown in the inoculated plates following incubation.

Statistical analysis

The Statistical Package for the Social Sciences (SPSS) v.20.0 for Windows (SPSS, SAS Institute Inc. Cary, USA) was used to conduct the statistical analysis. Descriptive statistics like mean and standard deviation were calculated by analyzing the data. The one-way ANOVA test with a 95% confidence interval using Duncan's Multiple Range Test was used to evaluate group differences. Value of $p < 0.05$ was regarded as statistically significant.

3. Results

Different bacterial strains were isolated based on the morphological distinction of individual colonies on dilution plates. They were then tested on TA and TBA media for lipase production. Of all the isolates, 29 were found to be lipase positive. Nine isolates demonstrated improved lipase production following rigorous screening (based on the severity of the opaque zone in TA medium and the creation of clear zone in TBA medium). The clear zone formation in TBA medium by the isolate is shown in Fig. 1. The strain that produced the most lipase among them was S_3T-9. Photomicrograph of this isolate is shown in Fig. 2. The bacteria was then molecularly identified as *Bacillus subtilis* 20B using 16S rRNA gene sequencing. Phylogenetic tree was constructed by neighbor joining method and shown in Fig. 3. This strain was later employed to optimize the production of lipase.

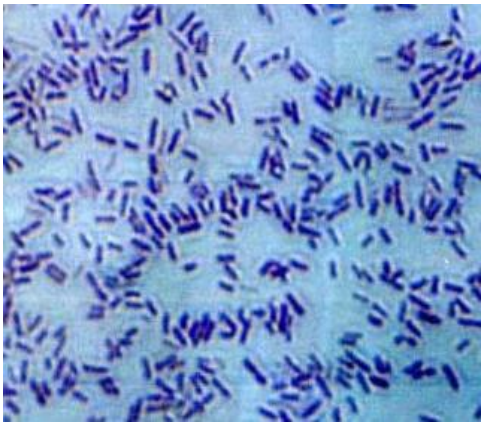

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Fig. 1: Photograph showing lipase producing bacterial colonies developed on TBA plate.

Fig. 2: Photomicrograph of strain S_3T-9.

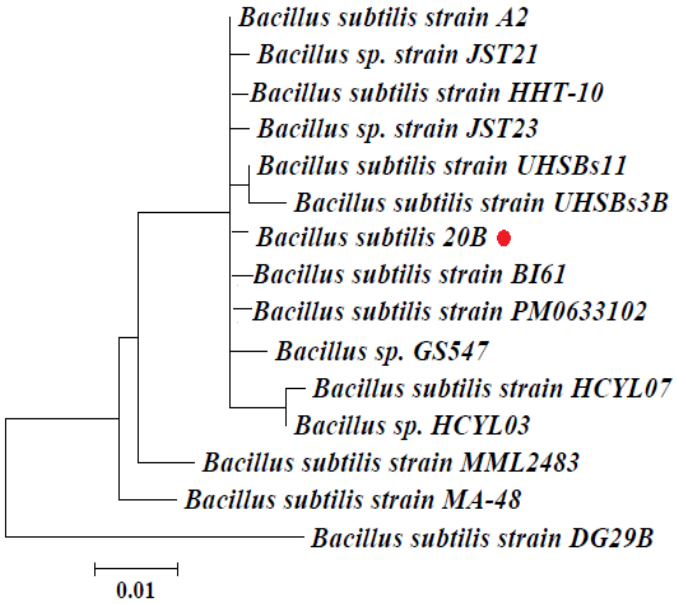

Fig. 3: A neighbor-joining phylogenetic tree of *B. subtilis* 20B.

Effects of NaCl concentration on lipase production

The effect of NaCl concentration on lipase production is shown in Fig. 4. The result indicated that lipase synthesis was impacted by increased salt content. A decrease in lipase synthesis was noted in response to increased NaCl concentration. At 0.5% NaCl, the maximum enzyme production (17.28±0.75 U/ml) was observed.

Optimization of better carbon source concentration on lipase production

Since starch was shown to be appropriate for lipase production, different quantities of starch (0.5 – 3.0%, w/v) were added to the medium to examine the impact on lipase production by the *B. subtilis* isolate. At 1.5% starch, the maximum enzyme activity (37.39±0.67 U/ml) was observed (Fig 5).

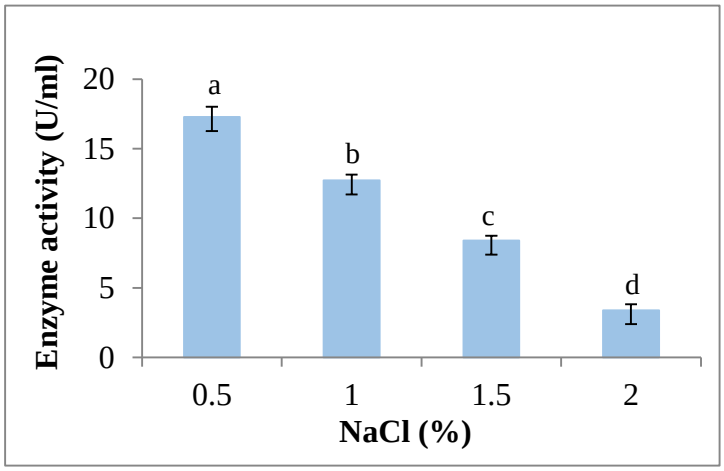

Fig. 4: Effects of NaCl on lipase production of *B. subtilis* 20B.

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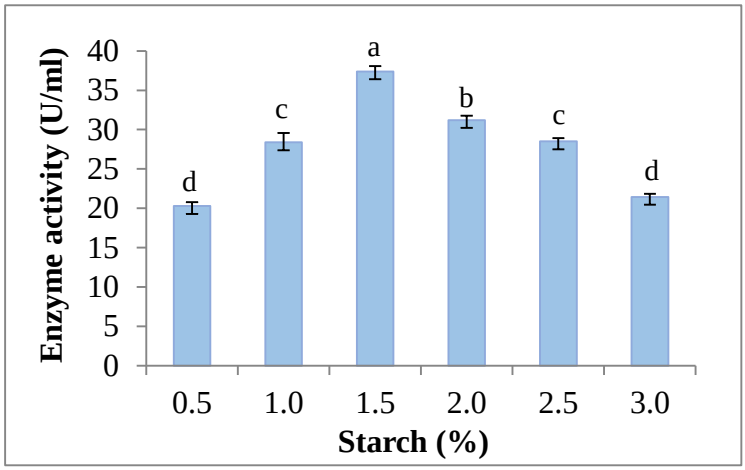

Fig. 5: Effects of starch concentration on lipase production of *B. subtilis* 20B.

Optimization of better organic nitrogen source concentration on lipase production

Effects of the concentration of better organic nitrogen source (yeast extract) on lipase production is shown in Fig 6. Since yeast extract was shown to be more effective for *B. subtilis*, different amounts of yeast extract (0.5–3.0%, w/v) were added to the medium to examine the impact on lipase production. At 1.5% yeast extract concentration, the maximum level of lipase production (25.17±0.67 U/ml) was observed.

Optimization of better inorganic nitrogen concentration on lipase production

Among different inorganic nitrogen sources, ammonium chloride was the most effective for lipase production of *B. subtilis*. Consequently, the medium was supplemented with varying amounts of ammonium chloride. It was shown that up to 1.5% ammonium chloride concentration boosted lipase synthesis, after which it decreased (Fig. 7). Ammonium chloride achieved lipase activity of 17.22±0.51 U/ml at this concentration.

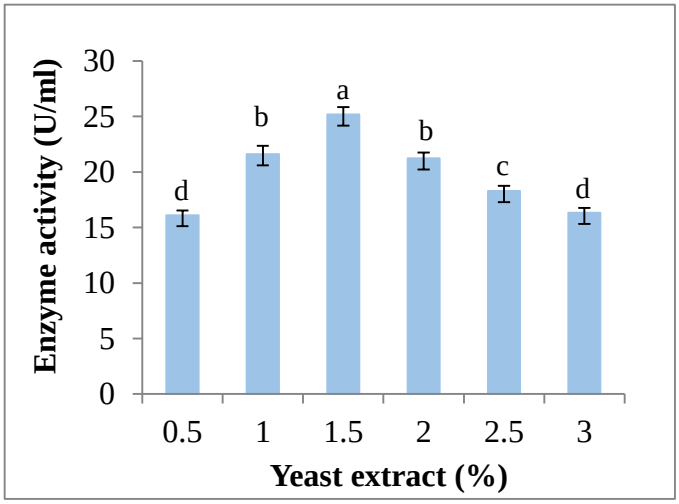

Fig. 6: Effects of yeast extract concentration on lipase production of *B. subtilis* 20B.

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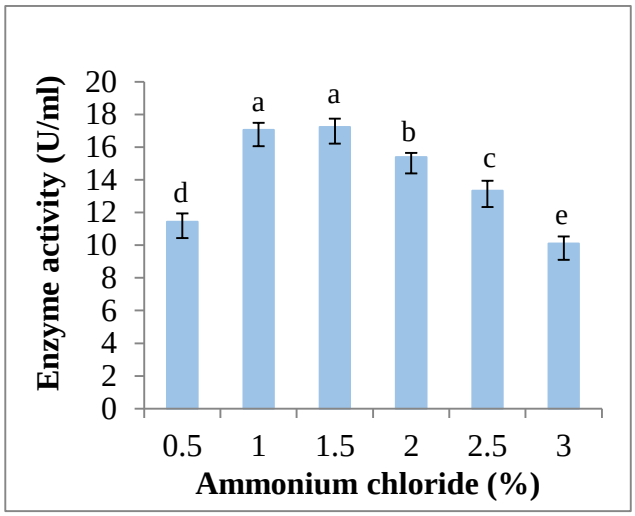

Fig. 7: Effects of ammonium chloride concentration on lipase production of *B. subtilis* 20B.

Effects of substrate concentration on lipase production

By incorporating different concentrations of olive oil (0.5–3%, v/v) into the medium, the impact of lipid as substrate on lipase synthesis was investigated. Lipase production was not significantly impacted by the content of olive oil, and the maximum activity (11.72±0.25 U/ml) was seen at 1% olive oil concentration (Fig. 8).

Effects of basal media on lipase production

Five standard basal media were examined for improved lipase production. Nutrient Broth (NB) medium shown to be more effective basal medium for lipase synthesis in this experiment. In NB medium with olive oil as the lipid substrate, *B. subtilis* demonstrated the highest lipase activity of 16.28±0.42 U/ml (Fig. 9).

Estimation of bacterial growth

The serial dilution plate technique was used to conduct this experiment at 12 h intervals for a total of 96 h. The bacterial growth pattern during lipase synthesis under all evaluated ideal conditions is displayed in Fig. 10. Initial cell density of the isolate was 1.56×10^3 cfu/ml. Increasing the incubation time showed that lipase production had been initiated slowly after 12 h and at 48 h the bacteria had obtained logarithmic growth phase. The viable count result showed that there was an increase in the number of cells from time 84 h in *B. subtilis* and then decreased as the time progressed. The isolate showed highest growth (6.9×10^7cfu/ml) at 84 h of incubation and cell number decreased over this time. Lipase production was the highest in exponential growth phase at 36 h of incubation by the isolate.

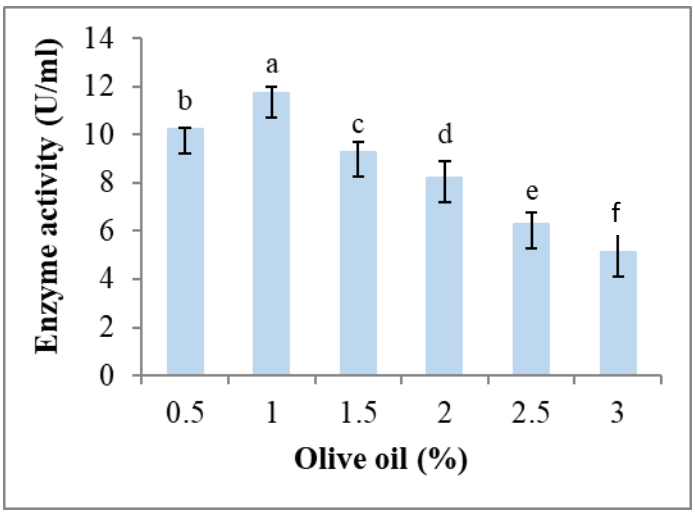

Fig. 8: Effects of substrate (olive oil) concentration on lipase production of *B. subtilis* 20B.

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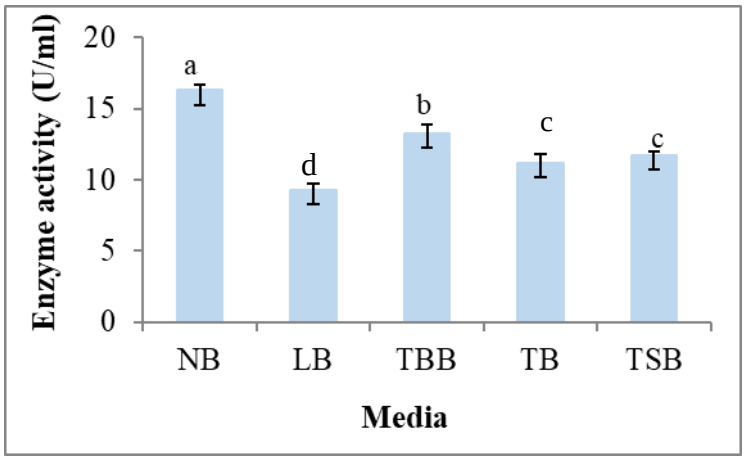

Fig. 9: Effects of basal media on lipase production of *B. subtilis* 20B.

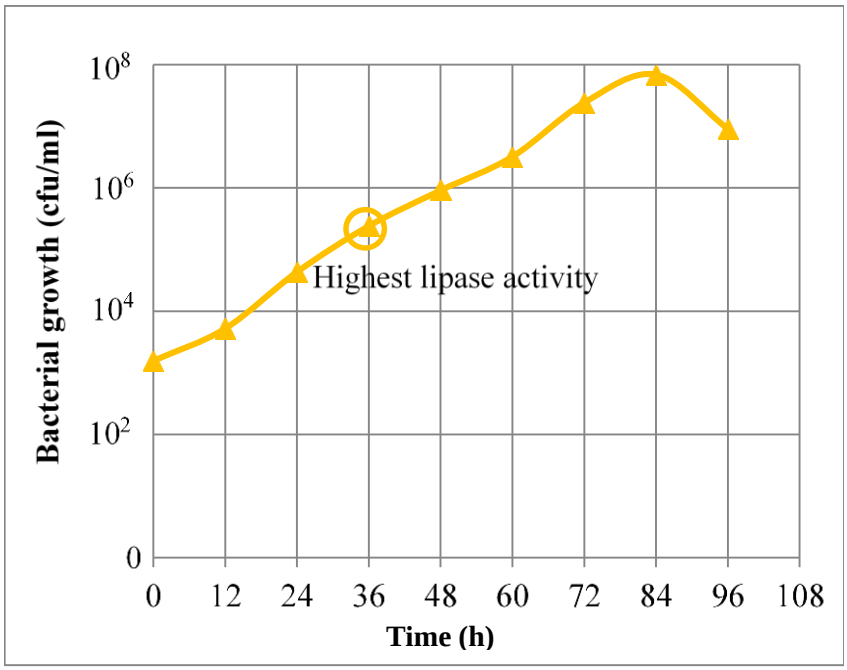

Fig. 10: Growth pattern and lipase activity of *B. subtilis* 20B.

4. Discussion

Different bacterial strains were separated based on the morphological distinction of individual colonies on dilution plates. They were then tested on TA and TBA media for lipase production. *Bacillus subtilis* 20B, a molecularly identified lipase producer, was the most promising. This isolate was then chosen in order to optimize the synthesis of lipase.

Different NaCl concentrations were added to the production medium in order to optimize the NaCl concentration in lipase production. *B. subtilis* had the maximum activity (17.28±0.75 U/ml) in this instance at *B. pumilus*. 0.5% NaCl. Sangeetha et al. (2014) similarly achieved this result, obtaining a high lipase yield in *Bacillus pumilus* SG2 with 14.98 U/ml at 0.5% salt concentration.

The carbon source, which also serves as an inducer for lipase formation, makes up the majority of the media used to produce lipase (Lotti et al., 1998). At 1.5% starch, the isolate reached its maximal lipase (37.39±0.67 U/ml). When Joseph et al. (2012) employed starch to produce lipase in *Bacillus sphaericus* MTCC 7526, they likewise obtained this result (23.67 U/ml). Sahasrabudhe et al. (2021) showed the similar result in

In this study, *B. subtilis* attained maximum lipase (25.17±0.67 U/ml) at 1.5% yeast extract. Similar outcome (20 U/ml) was obtained with yeast extract for *Bacillus* sp., as reported by Bora & Bora (2012). Sharma et al. (2002) and Bhattacharya et al. (2016) demonstrated that the bacteria, particularly different thermophilic *Bacillus* spp. and *Pseudomonas* spp., were able to produce larger amounts of lipase when organic nitrogen sources such peptone and yeast extract were utilized. According to Noormohamadi et al. (2013), the production of lipase was increased when olive oil was combined with other nitrogen sources. It was discovered that organic nitrogen sources outperformed inorganic ones. This result was consistent with studies on *Pseudomonas* sp. lipase production (Gupta et al. 2004). It has also been shown that certain bacteria respond well to inorganic nitrogen sources like ammonium chloride.

The synthesis of lipase was significantly influenced by the substrate, particularly the lipid concentration of the fermentation medium. According to Novototskaya-Vlasova et al. (2013), lipase activity is increased when olive oil and carbon sources are combined. Olive oil and carbon source in the growing medium significantly increased the isolate's lipase activity in the current investigation. Several thermophilic *Bacillus* species have been shown to produce large amounts of lipase when olive oil is added to the growth medium as a carbon source (Eltaweel et al., 2005). According to Muralidhar et al. (2001), olive oil was a more effective carbon source for lipase synthesis than glucose. In their investigation, Habibollahi and Salehzadeh (2018) noted that the medium's composition had a significant impact on lipase production.

During the estimation of bacterial growth, the time of incubation showed sharp decrease in lipase activity after 36 h in *Bacillus subtilis*. Following these times, the enzyme tends to decline, indicating that it may have either been broken down or rendered inoperable as a result of a decrease in lipidic substrate or an increase in acidity following medium ingestion. Kathiravan et al. (2012) have similarly documented this tendency with *Pseudomonas aeruginosa*.

5. Conclusion

About 29 bacterial isolates were obtained from organic waste which were evaluated for their ability to produce lipase. Among them, strain S_3T-9 exhibited significant lipolytic activity which was molecularly identified as *B. subtilis* 20B. This study looked into improving the culture conditions to help the isolate produce more lipase. It was discovered that the factors of NaCl, carbon source, nitrogen source, substrate concentration and basal media had a substantial impact on lipase synthesis. The best culture parameters for the indigenous isolate to produce maximum lipase were examined in this work and they may serve as a baseline for future research involving the treatment of lipid-rich wastewater.

6. Acknowledgements

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7. Conflict of interest

The authors declared there is no conflict of interest.

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Analysing Factors Affecting Customer Satisfaction with Sena-Kallayan Songsthan's Consumer Products

Md Wahidul Haque[a] , Md Enamul Islam[b] *

[a]*Academy of Social Science Research, Bangladesh*
[b]*Rajuk Uttara Model College (RUMC), Uttara Model Town, Dhaka-1230, Bangladesh*

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ABSTRACT

Sena Kallayan Songsthan is well-known for its quality products in Bangladesh. The business organization is looked after by the Bangladesh Armed Forces. Since the independence of the country, Sena Kallayan Songsthan has kept its footprint in various types of consumer products as well as some heavy machinery products. However, no known empirical research was noticed for assessing the customer satisfaction of the industry. Three important parameters of customer satisfaction were considered in this study to find out the predictive relevance of product quality, service quality and information quality.

Introduction

In today's information age, the widespread extension of business information technology has replaced the traditional way of public interaction. Entrepreneurs are moving forward in a span, the necessity of accessing a large audience with improved operational efficiency, product quality and service quality (Uddin and Cheng, 2014). The proliferation in technology usage is observed in organisations, while entrepreneurs face a tremendous challenge to providing the best service with good quality products/s while keeping the consumer informed. The significance of customer satisfaction is recognised in a commercial enterprise (Raja Irfan *et al.*, 2014). Customers are sources of revenue that ensure profit in steady companies. Companies which know how to keep their customers happy can experience more excellent financial stability. Customer satisfaction is an essential component of future business. Satisfaction is a satisfactory explanation. It is a judgment about the nature and quality of the product itself that provides a pleasurable experience that contributes to the overall fulfilment. Regular research on consumer satisfaction helps business organisations change their business strategy (Uddin and Cheng, 2014).

Customer satisfaction is usually associated with the product quality and service quality provided by the entrepreneurs, and if the consumers are informed about the product. These factors together can represent consumer satisfaction. As a result, the business owner utilises various strategies to survive (Tuan and Rajagopal, 2018). A key strategy to building a prosperous economy is to satisfy customers, which ensures long-term growth. Nowadays, organisations are aware of the importance of retaining the customer and continuing to strive to know why a black box of customer affects the brand choice to reduce the turnover rate (Hanif, Hafeez and Riaz, 2010).

In 1971, the Fauji Foundation came into being as the Sena Kalyan Sangstha (SKS). SKS was officially renamed on 01 July 1972. An organisation devoted to the welfare of retired, discharged, and released personnel of the Bangladesh Armed Forces and their dependents. The vision and mission of this commercial organisation controlled by the Bangladesh Armed Forces Division are "To serve the entire community of the retired armed forces personnel by generating maximum profit through commercial ventures utilising its resources efficiently and distributing the profit by a wide range of welfare activities while focusing on future growth in a sustainable manner for a broader range of welfare" (https://www.senakalyan.org/, no date). The organisation has various consumer products and services like cement, food and oil, bottled drinking water, electric appliances, textiles, insurance and tours and travel services.

Research on consumer satisfaction is a continuous process and never-ending, primarily when multi-national and multi-dimensional companies operate in the same market. An experimental study is necessary to understand the factors affecting user satisfaction with any organisation's consumer products and services. The research objective is to identify the factors affecting customer satisfaction with SKS's consumer products.

***Corresponding Author:** Md. Enamul Islam *
Email Address: enamul5085@gmail.com

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Literature Review

Today's consumer product manufacturing is faced with multi-dimensional challenges. The manufacturers need to emphasise more on the department's ability to support the product. They were reflecting the application of technology and engineering in products and services—the type and quality of the supplier's response. Evaluate suppliers' ability to meet deadlines and process efficiently. Supplier service provided to customers. Complaint management. Weight, durability, price and performance of the item. The supplier's mannerisms and interactions. Supplier's ability to cover the life cycle of a customer. Comprehensive and uncomplicated functions and operations (Raja Irfan *et al.*, 2014).

It is improbable that the manufacturer would be able to provide all the necessary features. It is good and bad in products and services, such as those that delight customers or ones that irritate them. The final opinion is the result of a lot of customer feedback over time. The greater the good aspects, the more satisfied a customer is with the purchase. The service provider's intended outcome should always be to enhance the positive feelings of all its customers to increase customer satisfaction. The supplier must provide a means of augmenting its positive aspects by evaluating customer information using experimental research. Customers' likes and dislikes vary to some extent. Therefore, it is essential to focus on individual requirements and target customers (Tojib, Sugianto and Sendjaya, 2008).

Service quality generally focuses on what customers expect regarding performance and how well they meet these expectations. A business with high quality service can adapt to changing customer demands while at the same time maintaining quality. Service quality, customer satisfaction, and a firm's business strategy should be priorities for its overall strategy. In addition to measuring and reviewing customer-related strategies, regular monitoring and evaluation of customer needs can help managers implement the products/services that customers value the most, while also retaining existing customers. Second, managers should view their organisation as a complex system comprised of many components and, more importantly, managers should put their efforts into bringing all these different components together to serve a common objective. The significant contribution of previous research in customer satisfaction-related studies is to test various constructs in relationship marketing literature, such as service quality, customer satisfaction, and customer loyalty, to test their interrelationships in a different context. Satisfaction is determined by how much a customer likes the service of the manufacturer. Therefore, a hypothesis can be developed that customers' satisfaction is significantly influenced by the service quality provided by the manufacturer or the distributor/supplier (H_1).

Product quality involves incorporating attributes committed to meeting needs (wants) and providing customers with loyalty by improving goods and services (products) and making them free from any defects or abnormalities. A pictorial view of the attributes of product quality can be seen in Figure 1. Most businesses will not succeed if they cannot build confidence with prospective customers; countless opportunities are lost when manufacturers fail to meet customer choice and demand. However, by having the confidence and loyalty of consumers, the business has the freedom to raise prices without losing the same level of consumer loyalty. Maintaining and delivering high-quality products and services is an effective way to encourage consumers to appreciate and build trust in the products they purchase. Kaniganat and Chaipoopirutana (2014) have concluded that customer satisfaction is directly influenced by product quality, while indirectly through the perception of price fairness.

One aspect of quality is the look, feel, sound, taste, and smell of a product. The product's look, precisely the colours, prints, shapes, textures, and features, sets it apart from its competitors. Customers find these kinds of details beneficial, which is why they are tempted to buy. The business organisation should always have a focus on retaining customers. High-quality products have low complaints and provide great profit (Li, 2013). A satisfied customer is more valuable to the organisation, and customers who are buying from it for a long time will produce a higher profit.

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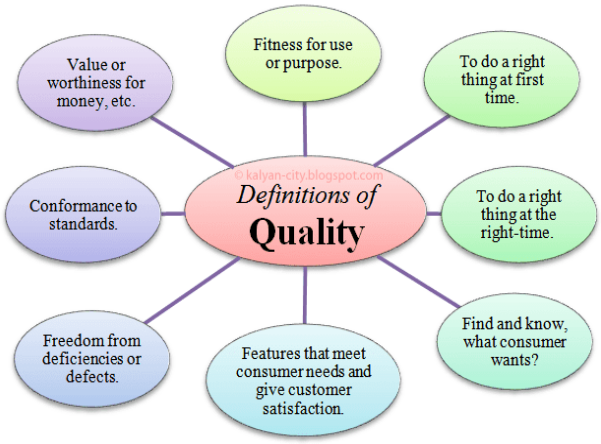
Figure 1: Various attributes of product quality, adapted from Caramela (2020)

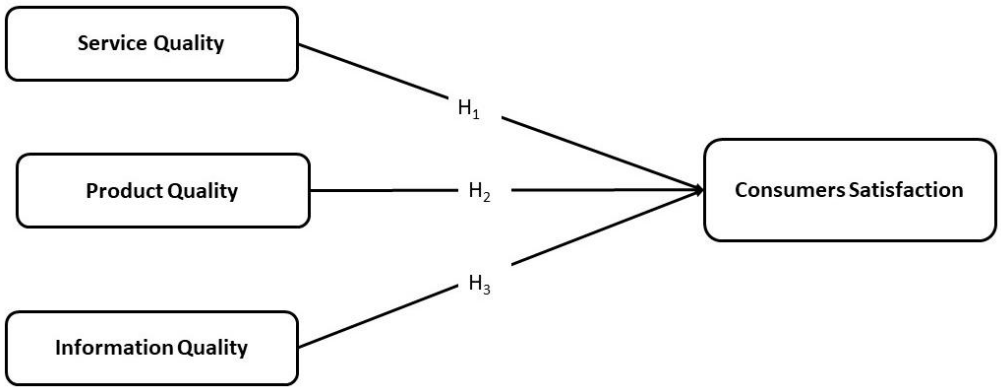


They are generally able to offer the lowest service cost and can be used to offer premium services. They act as brand ambassadors for the supplier, encouraging others to purchase the product. Hence, the organisation needs to ensure good quality products in the market and nurture their customers to create a strong bond with them in the short run and then focus on higher profits in the long run over the whole life cycle of customers. Therefore, it can be hypothesised that product quality significantly affects consumer satisfaction (H_2).

Information quality refers to the value of the information and the usefulness or utility of the given information. Good information is that which is applied and adapted to solve problems. Recent studies show that useful information contains numerous qualities and characteristics. Useful information is relevant to the problem and sufficiently accurate for its purpose, complete in terms of substance, reliable and targeted to the right audience (DeLone and McLean, 2003). Business profit depends on selling products. Unlike other factors, information quality also matters most when today's consumer has easy access to the information system. It is the supplier or manufacturer's prime responsibility to provide timely and necessary information to the consumers. One best ways to keep the customers informed is through mass media advertisement and online platforms (Alshikhi and Abdullah, 2018).

Information quality can be ensured in terms of accuracy, timeliness, completeness, relevance, and consistency. The more quickly and precisely entrepreneurs can provide the consumer's information, the better marketing they can achieve. Easy access to information technology, such as the internet, makes consumers' lives more comfortable to finding the right quality products in the market. Even a consumer who wishes to purchase spices from the local market nowadays days a Google search to find the best quality products. Therefore, it can be hypothesised that entrepreneurs' ability to produce information quality might significantly influence customer satisfaction (H_3). A pictorial view of the conceptual framework is shown in Figure 2.

Figure-2 : Hypothesised relationship of latent constructs



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Methods and Materials

This research aims to study the influence of service quality, product quality, and information quality on SKS's consumer products customer satisfaction. The descriptive research gathers information about how behaviour occurs in particular situations, not how it is performed in controlled situations. Surveys can only provide necessary information on what, where, when, who, and how something occurs, not why it occurs. Commonly used in survey research are the observation, case study, and survey methods. The survey is a research technique that involves the collection of a data set that would then be analysed by the researcher. A questionnaire survey was developed to get a response from the target population. This research is confined to the consumer's items such as bakery, spices, edible oil, cosmetics, soap, food grains and other miscellaneous items produced by the SKS and sold in Canteen Store Department (CSD) shops and local markets in and around Dhaka city.

Apart from the demographic variables such as age, gender, marital status, and average monthly purchase, the researchers used four sub-scales to measure the latent constructs. The subscales are adapted from existing literature. For example, the researcher has adapted the scale developed by Kaniganat and Chaipoopirutana (2014) for measuring the endogenous latent construct "Customer's Satisfaction". The Sub-scale to measure "service quality" exogenous latent construct was adapted from Masukujjaman (2010). The items to measure the product quality variable were adapted from Li (2013). The information quality sub-scale was adapted from DeLone and McLean's "Information Service" success model (2003). Since the researcher adapted the sub-scales from existing literature, which was conducted in a developed nation, a pilot study was necessary to find out the validity and reliability (Kumar, 2011). The researcher conducted a pilot study with 65 respondents.

The targeted populations are the 18 to 70-year-old customers in and around Dhaka city. The researcher has collected data from 384 samples (the number of populations is unknown). The unit of analysis is individual customers who have consumer products in their shopping list. The researcher has used a purposive simple random sampling technique for selecting the samples (Sikder, 2019). The researcher analysed the collected data with Computer-Aided Quantitative Data Analysis Software (CAQDAS). The fifth-generation SmartPLS software was used to test the hypotheses. Partial Least Squared Structural Equation Modelling (PLS-SEM) is a variance-based structural equation modelling technique that has become very popular in management and social sciences in recent years. It can test complex models (Nitzl, Roldan and Cepeda, 2016, P. 4).

Result and Discussion

The pilot study achieved an .835 Cronbach Alpha with 42 items in 4 variables; however, expert opinion was taken from marketing research experts who have suggested reducing items. The researcher conducted confirmatory factor (CFA) analysis and kept 28 items besides four demographic variables. The final study was conducted from July 2020 to November 2020. The research has confirmed the data purification before statistical analysis. Mahalanobis Distance test (D^2) was used to find out potential outliers. The D^2 value was (40.3397) below the critical value considering the degree of freedom (28) and $P<.05$. The result indicates that the data set is free from outliers. However, the data set fails to achieve a normal distribution of the data.

Common Method Bias (CMV) has been generally agreed to be a significant issue associated with self-report surveys (Lindell and Whitney, 2001; Reio, 2010; Henseler *et al.*, 2014; Vishwanath, 2017). Harman's single-factor test was performed with confirmatory factor analysis on all 28 items that measure the entire construct as an unrotated principal factor to determine the number of factors that account for the construct's variance. A single factor explained 33.18% total variance, which is well below a 50% variance. Thus, CMB was not a potential threat to the data set.

Regarding the multicollinearity, both inner and outer model Variance Inflation Factors (VIF) were below five, indicating the data set is free from collinearity issues. Construct validity and reliability were achieved through composite reliability and Average Variance Extracted (AVE) as seen in Table 1. The items' outer loadings were also above 0.708 (except one item in service quality, which loaded with 0.532 and was deleted from the data set), measuring the reliability of the data set as can be seen in Figure 2.

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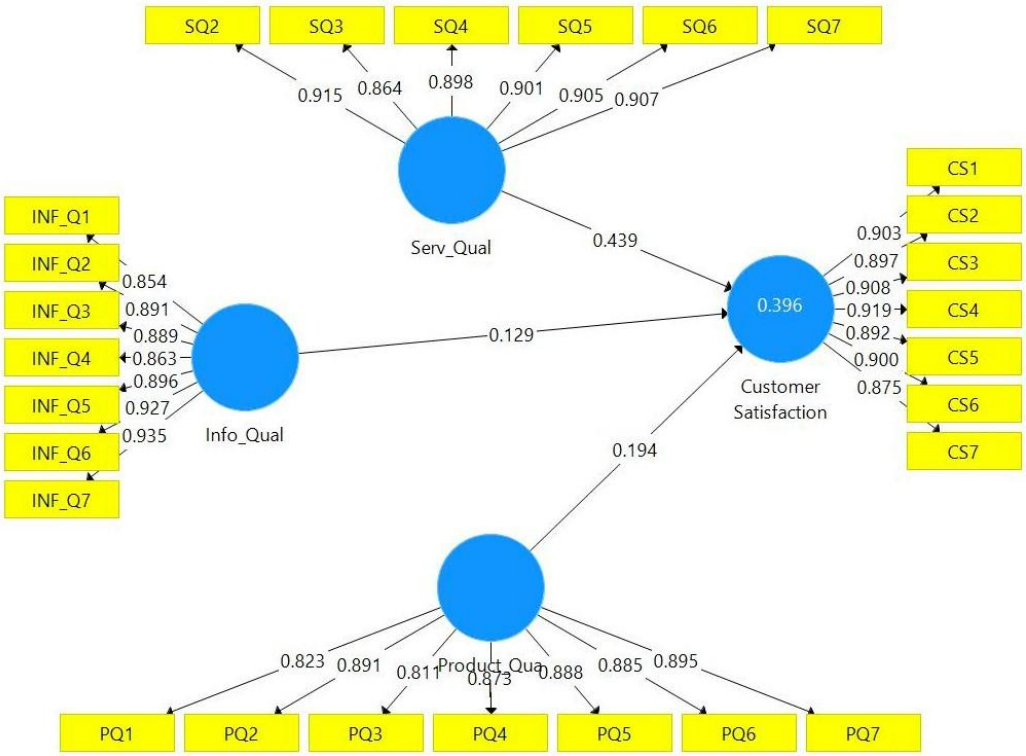
Table 1: Construct validity and reliability result (SmartPLS algorithm report)

Latent Constructs	Cronbach's Alpha	rho_A	Composite Reliability	AVE
Customer Satisfaction	0.961	0.963	0.967	0.809
Info_Qual	0.958	0.961	0.965	0.799
Product_Qual	0.945	0.954	0.955	0.752
Serv_Qual	0.952	0.953	0.962	0.807

Figure 2: Showing the indicators' outer loadings.



Source: PLS Algorithm report

Table 2: Respondents' profile (n-384)

Variables	Codes	Frequency	Per cent
Gender	Male	288	75.0
	Female	96	25.0
	Below 30 yrs	92	24.0
Age	30 to 40 yrs	119	31.0
	41 to 50 yrs	96	25.0
	Above 51 yrs	77	20.1
Marital Status	Married	345	89.8
	Unmarried	24	6.3
	Divorced	13	3.4
	Missing Value	2	.5
Average Shopping	Below 5000 taka per month	237	15.6
Expenditure Per Month	5000 to 10000 taka	102	40.1
	Above 10000 taka	45	44.3
Purchase Frequency of	Regular	115	29.9
SKS products	Once in a month	175	45.6

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	Some time	94	24.5
Knowledge about SKS Products	Yes	179	46.6
	No	204	53.1
	Missing Value	1	.3

As shown in Table 2, 75% of respondents are male, while 25% are female, indicating that male consumers often purchase SKS consumer products. An average consumer spent less than 5000.00 taka per month. 45.9% of respondents purchase SKS consumer products once a month. 53.1 % of respondents opined that they do not have any pre-decision or knowledge about SKS products.

Hypotheses Testing

The research was conducted to find out the predictive causal effect of "service quality", "product quality" and "information quality" on customer satisfaction while purchasing SKS consumer products. Bootstrapping procedure reports provide empirical t-statistics (obtained by dividing the path coefficient value by standard error) and 'P values' (the probability of erroneously rejecting the null hypothesis). The empirical t value is compared with the critical value to determine if it is higher than the critical value, which is desired. The critical t values are 2.57, 1.96, and 1.65 for a significance level of 1%, 5%, and 10%, respectively, for two-tailed tests (Wong and Kwong, 2013).

H_1 was a premise in a prediction that service quality might affect consumer satisfaction. The path relationship is significant at 1 per cent (t=7.527; p-value is 0.000). This statistical analysis rejects the null hypothesis (referring to Table 3). There is a positive effect of service quality on customer satisfaction. Therefore, the study rejects the null hypothesis and found that the alternative hypothesis is **supported.**

Table 3: Bootstrapping result (5000 sub-sample)

Path Relationship	Hypothesis	Original Sample	Sample Mean	Standard Deviation	T Statistics	P Values
Service Quality -> Customer Satisfaction	H_1	0.439	0.441	0.058	7.527	0.000
Product Quality -> Customer Satisfaction	H_2	0.194	0.193	0.060	3.225	0.001
Information Quality -> Customer Satisfaction	H_3	0.129	0.130	0.049	2.620	0.009

It was predicted that product quality might have a significant effect on customer satisfaction (H_2). The path relationship is significant at 1 per cent (t=3.225; p-value is 0.001). This statistical analysis rejects the null hypothesis (referring to Table 3). There is a positive effect of product quality on customer satisfaction. Therefore, the study rejects the null hypothesis and found that the alternative hypothesis is **supported.**

The third hypothesis was to test the effect of information quality on customer satisfaction. The path relationship is significant at 1 per cent (t=2.620; p-value is 0.009). This statistical analysis rejects the null hypothesis (referring to Table 3). There is a positive effect of service quality on customer satisfaction. Therefore, the study rejects the null hypothesis and found that the alternative hypothesis is **supported.**

Model Assessment

The coefficient of determination (r^2 value) depicts the structural model's predictive accuracy and is calculated as the squared correlation between a specific endogenous construct's actual and predicted values (Hair et al., 2014). The r^2 gives the combined effects of independent variables on the dependent variable, i.e. it represents the amount of variance in the endogenous constructs explained by all of the exogenous constructs linked to it (Tabachnick and Barbara, 2019). The study achieved (referring to Figure 2) an r^2 value of 0.396, indicating that the independent variables together have 39.6% variance on the dependent variable.

Effect Size can be calculated as {f^2 = (r^2 included - r^2 excluded)/(1- r^2 included) where r^2 included and r^2 excluded are the r^2 values of the endogenous latent variable when a selected exogenous latent variable is

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included in or excluded from the model. Cohen (1988) has suggested that f^2 values: 0.02, 0.15, and 0.35, respectively, represent small, medium, and large effects of the exogenous latent variable. Table 4 shows the effect size (f^2) of the independent variables on the dependent variable.

Table 4: Effect Size

Independent Variables	Dependent Variable (Customer Satisfaction)	Decisions
Information Quality	0.023	Small Effect
Product Quality	0.043	Small Effect
Service Quality	0.199	Medium effect

Standardised Root Mean Square Residual (SRMR) reading has grown in popularity, and the researchers considered that an SRMR value below 0.08 represents a useful result. Table 4 noted that the SRMR value is 0.044 (<0.8), indicating that the model fits the goodness of fit criterion.

Hair et al. (2014) have also suggested that the Normed Fit Index (NFI) value of a model should be above 0.9 to achieve goodness of fit (The NFI constructs a Chi² score based on the hypothesis tested and compares it to a tangible benchmark value). As shown in Table 5, the NFI value is 0.939, above the recommended threshold (>0.9). This data analysis confirms further goodness of fit of the model.

Table 5: SRMR and NFI report

Result	Saturated Model	Estimated Model
SRMR	0.044	0.044
d_ULS	0.727	0.727
d_G	0.306	0.306
Chi-Square	667.447	667.447
NFI	0.939	0.939

Conclusion and Guideline for Future Research

Assessing customer satisfaction is a continuous process. Business needs to remain updated and keep their performance increasing. This research's objective was to test the effect of a defined set of variables on the customer's satisfaction with SKS's consumer products. All three hypotheses were supported, indicating that service quality, product quality and information quality significantly affect the customer's satisfaction. 53.1% of respondents have limited or no knowledge about SKS products, indicating that product information has not reached the customers. This research might help managers of SKS to provide better service, increase product quality and inform the customers about the product (through advertising).

The research is not free from limitations. The researcher could select some more variables, like store location, customer motivation, perceived usefulness, and user benefit as independent variables. The purposive sampling may limit the generalizability of the result. Due to time and funding availability, the researcher could not conduct a mixed-method or qualitative research (human behaviour also demands opinions and comments from the people involved), which could have made the research more authentic as suggested by Ivanko (2003). Future researchers may expand the customer satisfaction study into a cross-sectional study.

Recommendations

The researcher, with his interest and inquisitiveness, has conducted this research. There was hardly any previous research noticed by the researcher on the subject matter. This research might become a benchmark for future research for SKS. The researcher makes the following recommendations:

a. SKS may conduct an in-depth study to find out customer satisfaction and net benefits following Delone & McLean's information success model.
b. SKS management might seek more opportunities for keeping their customers informed through a visual and printed advertising system.
c. The customers seem to be satisfied with the product quality; however, information quality needs improvement.
d. More dealers may be employed for distribution, and more outlets might be established to reach out to the customers.

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Profitability and Multi-functionality of Integrated Enterprise Model Cattle Farming in Coastal Region of Bangladesh: A Socio-Economic Analysis

Salim Ahmed [a*], *Mohammad Fakhrul Alam* [a], *Shampa Roy* [a], *Fakir Azmal Huda* [b]
[a] *Rajuk Uttara Model College, Dhaka-1230, Bangladesh*
[b] *Bangladesh Agricultural University, Mymemsingh-2200, Bangladesh*

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ABSTRACT

This study aimed to assess the profitability of cattle farming with non-conventional by-product utilization, understand the economic benefits of livestock multi-functionality, and identify challenges in livestock farming in coastal Bangladesh. A quantitative, cross-sectional survey-based research design was employed. The study was conducted in the Khulna, Satkhira, and Bagerhat districts of coastal Bangladesh between November, 2024 and January, 2025. Data were collected from 120 randomly selected cattle farmers across 12 villages through face-to-face interviews using a pre-tested schedule. Data analysis involved descriptive statistics, farm budgeting techniques (Net Farm Income, Management Income), and a Problem Facing Index (PFI) to evaluate constraints. The integration of non-conventional by-products (cow dung stick, vermicompost, biogas) significantly enhanced profitability. Biogas integration yielded the highest Net Farm Income (BDT 316,632.10) and Management Income (BDT 124,132), representing a 47.51% and 76% higher income, respectively, compared to business-as-usual practices (NFI BDT 166,200.85; MI BDT 30,431.75). Farmers strongly perceived livestock's contribution to soil fertility (85% agreement) and food & nutrition (80% agreement). The primary challenges identified were disease occurrence (PFI: 310/360) and high feed prices (PFI: 285/360) in traditional systems, while bad odor (PFI: 260/360) and labor availability (PFI: 250/360) were key issues in integrated models. Multi-functional livestock farming, especially with biogas integration, is a highly profitable enterprise that substantially boosts household income, food security, and environmental sustainability in coastal Bangladesh. It offers a viable pathway for climate change mitigation through the valorization of manure. Policy interventions focused on increasing awareness, providing soft loans for technology adoption, and improving veterinary services are crucial for scaling these benefits.

1. Introduction

Livestock is an indispensable component of the agricultural farming system in Bangladesh, with the sector contributing 1.66% to the national Gross Domestic Product (GDP) in the 2015-2016 fiscal year. The importance of livestock extends beyond direct economic outputs of milk, meat, and eggs; it embodies a concept of multi-functionality, providing employment, draft power, and a source of organic manure for crop production. Traditionally, livestock, particularly cattle, serve as a critical support system for the livelihoods of millions of rural poor. Globally, livestock contributes about 40% to the agricultural GDP and is a cornerstone of livelihood for an estimated 1.3 billion people in developing nations (World Bank, 2008, 2009) with a growth rate over 1.27%.

In Bangladesh, recent innovations have highlighted the potential of cattle by-products, especially cow dung, as a valuable resource. The use of dung for vermicompost and biogas production presents an opportunity to create alternative income streams, enhance soil fertility, and provide a renewable energy source for rural households. This transition aligns with principles of a circular economy, turning a farm waste product into a valuable asset.

*Corresponding Author: Salim Ahmed
Email Address: Email: kbd.salim777@gmail.com

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Despite the recognized importance of livestock, a significant research gap exists in empirically quantifying the profitability gains from integrating these non-conventional by-product utilization methods into traditional cattle farming systems in coastal areas of Bangladesh. While the multi-functional roles are acknowledged, their specific socio-economic and environmental benefits—particularly the potential for climate change mitigation via biogas generation — remain under-evaluated. Farmers also face persistent challenges that limit productivity and the adoption of new technologies.

This study builds on existing literature that has explored the multi-functionality of livestock (Moyo & Swanepoel, 2010) and the economics of production systems (Sanpaolo, 2016), but provides specific, empirical data from the vulnerable region like coastal context of Bangladesh. This research, therefore, aims to address the aforementioned gaps. The specific objectives were:

1. To assess the profitability of cattle farming via enterprise model after integrating non-conventional by-product utilization in farming systems.
2. To understand the economic benefits derived from livestock's multi-functionality
3. To identify the primary challenges and obstacles faced by farmers in livestock farming.

2. MATERIALS AND METHODS

2.1. Study Area and Sampling

The study was conducted in the coastal region of Bangladesh, encompassing three districts: Khulna, Satkhira, and Bagerhat. These areas were selected purposively due to their significant engagement in cattle farming and their relevance to climate change discourse. From these districts, a total of 12 villages were selected for the survey. A comprehensive list of all households engaged in cattle farming was prepared for each village. Using a simple random sampling technique, 10 farmers were selected from each village, resulting in a total sample size of 120 respondents for the study.

2.2. Data Collection

Primary data were gathered through face-to-face interviews with the selected farmers using a pre-tested, semi-structured interview schedule. The schedule was designed to capture detailed information on:

- Socio-economic and demographic characteristics of the farmers.
- Costs and returns associated with cattle rearing, including both business-as-usual (BaU) practices and integrated systems utilizing by-products (biogas, vermicompost, cow-dung stick).
- Farmers' perceptions regarding the multi-functional contributions of livestock.
- Challenges and constraints faced in livestock production.

The interview schedule was pre-tested with non-sample farmers and modified to ensure clarity and relevance. The data collection was performed by the researcher to ensure accuracy and consistency.

2.3. Analytical Techniques

The collected data were coded, tabulated, and analyzed using Microsoft Excel and appropriate statistical tools. The following analytical methods were employed:

- **Descriptive Statistics:** Frequencies, percentages, and means were used to summarize the socio-economic characteristics of the sample farmers.
- **Profitability Analysis:** Farm budgeting and cost-return analysis were used to assess profitability. Key indicators were calculated as follows:
  - **Gross Output:** The total value of all products and services from the enterprise, including milk, change in animal inventory, and the value of by-products (manure, biogas, etc.).
  - **Net Farm Income (NFI):** Calculated by subtracting total costs (variable and fixed) from the Gross Output.
  - **Management Income (MI):** Calculated by subtracting the opportunity cost of family labor and operating capital from the Net Farm Income to determine the return to management.
  - **Problem Facing Index (PFI):** To assess the severity of problems faced by cattle farmers, a Problem Facing Index (PFI) was computed. Farmers were asked to indicate the extent of each problem on a four-point Likert scale: "very high" (4), "high" (3), "medium" (2), and "low" (1). The PFI for each problem was then calculated using the following formula:

$$PFI = \sum_{i=1}^{4} (S_i \times N_i)$$

Where:

S_i = Score given to the i-th response (4 for very high, 3 for high, 2 for medium, 1 for low).

N_i = Number of farmers giving the i-th response.

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The calculated PFI values allowed for a ranking of the problems from most to least severe.

The index for each problem was computed using the simplified formula:

$$PFI = (P_s \times 3) + (P_m \times 2) + (P_l \times 1) + (P_n \times 0) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where,

P_s = Number of the respondents with severe problem;

P_m = Number of the respondents with moderate problem;

P_l = Number of the respondents with low problem; and

P_n = Number of respondents having no problem.

3. RESULTS

3.1. Socio-economic Profile of Farmers

The majority of cattle farmers (43.33%) were in the most active age group of 30-40 years. The average family size was 5.4 persons, with most households (56.67%) having 2-4 members. In terms of education, 40% of farmers had completed primary education, while 6.67% were illiterate. Agriculture was the primary occupation for the majority (51.67%), while all 120 respondents engaged in livestock farming as a crucial subsidiary occupation.

3.2. Financial & Economic Profitability of Integrated Cattle Farming Systems

The integration of non-conventional by-product utilization significantly enhanced the financial performance of cattle farming compared to the business-as-usual (BaU) model. As detailed in Table-1, the biogas integration model yielded the highest returns. The Net Farm Income (NFI) for the biogas model was BDT 316,632.10, which is 47.51% higher than the NFI of the BaU model (BDT 166,200.85). The Management Income (MI) showed an even more substantial increase, rising from BDT 30,431.75 in the BaU model to BDT 124,132 in the biogas model—a 76% increase. The integration of cow dung stick production and vermicomposting also resulted in higher profitability than the BaU model, though to a lesser extent than biogas.

3.2.1. Financial Profitability of Integrated Cattle Farming Systems

After calculating the gross output; the total value was determined**. All the calculations are based on yearly output of five cattle.** From table-1, it is observed that the value of animals in the opening stocks is BDT 239,280.9 and closing stock was BDT 383,797.35. The value of product mainly from the milk sold was BDT 400750. The value of milk which used for farmers own consumption was BDT 12775. From the cow dung sold, the yearly income of the farmer is BDT 8000 and for the own consumption, it's valued for BDT 4000. For its closing stock the value was about BDT 5800. Now from the integration of business purpose, the cow-dung stick sold for BDT 18000. Beside this, the own consumption of the farmer for stick preparation is BDT 14500 per year. The calculated amount for vermi-compost sell is about BDT 32500; and for the farmers own need for composting; the amount is BDT 9500. In the integration of business model; the bio-gas production and sell amount was BDT 8400. It becomes very beneficial when the opportunity cost of the bio-gas is about BDT 18000; which means this amount for fuel purchase are being saved by this bio-gas generation in every farm household for cooking.

Calculation of Total Net Change in Inventory = (Value of closing stock + Sales value+ Consumed value) - (Bought + Opening Stock);

By using this formula; Total Net Change in Inventory comes to BDT 144516.45. Estimated gross output is BDT 144516.45; as the value of animals is BDT 413525; the value of milk product and lastly the value of cow-dung is BDT 17800 yearly/farm for 5-cattle together. Hence, Total Gross Output in the Business-as-Usual practice model is BDT 575841.45; whereas it comes to BDT 676741.45 in the Business Integration Model; thus, value addition amount is BDT 100900.00

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Table-1: Gross Output from Livestock Farming in Different Models

Items	Business-as-Usual Practice			Business Integration Model		
	Value of Animals BDT	Value of Product (Milk)	Cow dung (Tk/Year)	Cow dung Stick (Tk/Year)	Vermi-compost	Biogas
Opening Stocks	239280.9	0		0	0	0
Bought	0	0	0	0	0	0
Sold	0	400750	8000	18000	32500	8400
Consumed	0	12775	4000	14500	9500	18000
Closing Stock	383797.35		5800	0	0	
Total Net Change in Inventory	144516.45					
Gross Output of Livestock	144516.45	413525	17800	32500	42000	26400
Output from Business-as-Usual Practice: 575841.45				**Value added by Business Integration Model: 100900**		
Total Gross Output (575841.45+100900) =						676741.45

Source: Farm survey, 2024

Estimation of Gross Margin from Cattle Farming

The formula used: GM= TR -VC
Where,
GM= Gross margin;
TR= Total return
VC= Variable cost

From table-1, it got gross output as BDT 575841.45 in the Business-as-Usual (BaU) model and the variable cost of five cows per year was found 353086.692. As a result, the gross margin is amounted to BDT 222754.758 in BaU model (table-2). The gross Margin per five cow in cow-dung stick integration model is BDT 318217.258. In vermi-compost integration model, gross margin per five cow is BDT 309467.26; and the gross margin in bio-gas integration model is BDT 309467.25 as shown in table-2:

Table-2: Gross Margin Analysis of Various Models of Livestock Farming

Livestock Farming Model	Business-as- Usual Model	Business Integration Model		
		Cow-dung stick Integration	Vermi-compost Integration	Bio-gas Integration
Gross Output of Livestock	575841.45	676741.45	676741.45	676741.45
Variable Costs of five cows (BDT)	353086.69	358524.19	367274.19	248055.44
Gross Margin	222754.75	318217.25	309467.25	428686.00

Source: Farm survey, 2024

Estimation of Fixed Cost or Overhead Cost

Fixed cost of the farming system was estimated considering land rent on grazing land & farm shed, interest on capitalized value of animals, permanent labour, depreciation cost & interest on borrowed capital. For calculating the interest on capitalized value of animal; the following formula is used:

Interest on capitalized value of animals = [10% on {(Value of opening stock + value of closing stock) ÷ 2}]

The Interest on capitalized value of animals is BDT 31153.9125; Depreciation (10% on Cowshed and Machinery) and interest on borrowed capital is calculated respectively as BDT 15000 and 5000. Total fixed cost is BDT 56553.9125 for all models without the bio-gas integration model. Overhead cost of BaU model is BDT 56553.9125; cow-dung integration model is BDT 56553.91; in the vermi-compost integration model BDT 81553.91 have been estimated.

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Table-3: Fixed Cost or Overhead Cost of Business-as-Usual Model

Particulars	Cost (BDT)
Rent	
a. On Grazing Land (Average) 33 Decimal / year	2400
b. On Farm shed Area 15 Decimal	3000
Interest on capitalized value of animals	31153.91
Permanent labour	0
Depreciation (10% on Cowshed and Machinery)	15000
Interest on borrowed capital	5000
Total Overhead Cost	56553.91

Source: Farm survey 2024

Estimation of Net Farm Income

It considered fixed cost; cost of land rent, interest on operating capital, etc. Net income was calculated by deducting all costs (variable and fixed) from gross return. It is denoted as under:

Net Farm Income = Total Gross Margin - Overhead Cost

In the table-4; total gross margin is BDT 222754.75 and the overhead cost is BDT 166200.84; after necessary subtractions --- the Net farm income from BaU, cow-dung stick integration, vermi-compost integration and bio-gas integration models were BDT 166200.84; BDT 261663.3455; BDT 227913.34; and BDT 316632.0955 respectively. These values of Net farm income showed that the profitability of other three integration models are higher than the Business-as-Usual model in practice.

Table-4: Net Farm Income from Livestock Farms of Various Models

Livestock Farming Models	Business as usual model	Integration of Models		
		Cow dung stick Integration	Vermi-compost Integration	Bio-gas Integration
Total Gross Margin	222754.75	318217.25	309467.25	428686.00
Overhead Cost	56553.91	56553.91	81553.91	112053.91
Net Farm Income	166200.84	261663.34	227913.34	316632.09

Source: Farm survey 2024

Comparison among Livestock Farming Models in terms of their Net Farm Income

Table-5 showed that the business as usual model's net farm income is BDT 16620.8455; where it is BDT 261663.34; BDT 227913.34 and BDT 316632.09 respectively in the integration of cow-dung stick, vermicompost and bio-gas models. So, the value addition in the net income from cow-dung stick integration, vermi-compost integration and bio-gas integration model are BDT 95462.49; BDT 61712.50; and BDT 150431.25 respectively. This is a rise above the Business-as-usual model by 63.51%, 72.92%, and 52.49% of net farm income respectively. Therefore, the percentage of more income over the very common business-as-usual model by the cow-dung stick integration, vermi-compost integration; and bio-gas integration model are 36.49%, 27.08%, and 47.51% respectively. So, it can be concluded that the Business Integration Models have significantly increased the financial profitability of cattle farming.

Table-5: Various Model's Net Farm Income Comparison of Livestock Farming

Livestock Farming Models	Business-as-Usual in Model (BaU)	Integration model		
		Cow dung stick Integration	Vermi-compost Integration	Bio-gas Integration
Net Farm Income	166200.84	261663.34	227913.34	316632.09
Excess Income Over BaU Model	---	95462.49	61712.50	150431.25
Changes in Percentage	---	63.51%	72.92%	52.49%
Excess Income in Percentage	---	36.49%	27.08%	47.51%

Source: Farm Survey, 2024

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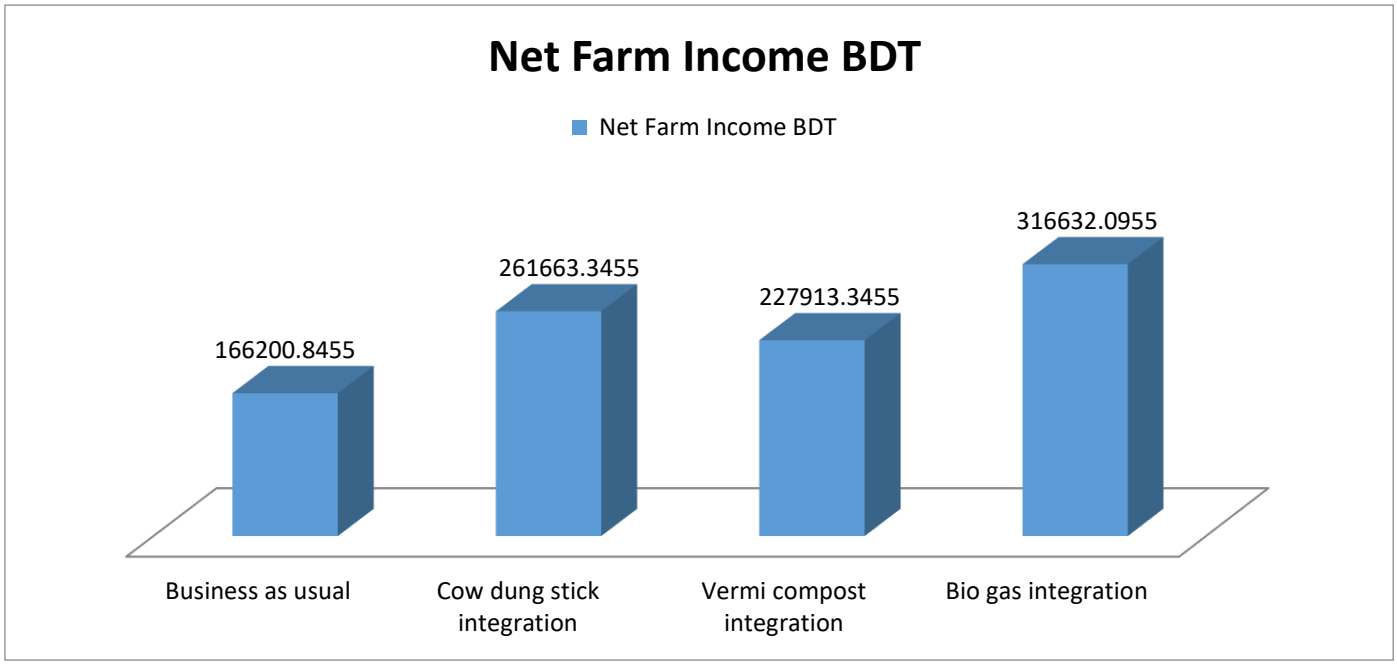

Fig-1: Showing Variations in Net Financial Income of Various Models of Cattle Farming Over the Business-as-Usual Model

3.2.2. Economic Profitability of Integrated Cattle Farming Systems

Operators Income

An operator income is the income which is considered as the actual operating return. To calculate it, the following formula is used;

Operator's Income = Net Farm Income - Opportunity cost of family labour

The opportunity cost of family labour is estimated as BDT 70000. So, the operator's income is calculated as BDT 96200.8455 in the table-6 in business-as-usual model. Besides in three models i.e in the cow-dung stick, vermi-compost and bio-gas integration model; the operator's income is BDT 191663.34, 157913.34 and 246632.09 respectively.

Table-6: Operators Income from Livestock farming

Livestock Farming Models	Business-as-usual model	Integration model		
		Cow-dung stick Integration	Vermi-compost Integration	Bio-gas Integration
Net Farm Income	166200.84	261663.34	227913.34	316632.09
Opportunity cost of family labour	70000	70000	70000	70000
Operators Income	96200.84	191663.34	157913.34	246632.09

Source: Farm survey, 2024

Operator's Labor and Management Income

Mean value of the operator's income is BDT 168870.65 and the value of Opportunity cost of family's operating capital is BDT11769.10; hence the value of 'Operator's labour and Management Income'=

[Operators labour and Management Income = (Operators Income - Opportunity cost of family operating capital)]

and it has been calculated as 84431.74 BDT. Besides, in the three models i.e. the cow-dung stick, vermi-compost and bio-gas integration model; the operator's income is BDT 179894.24, 144913.34 and 232132 respectively (table-7).

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Table-7: Operator's Labour and Management Income from Livestock farming

Livestock Farming Models	Business-as-usual model	Business Integration Models		
		Cow-dung stick Integration	Vermi-compost Integration	Bio-gas Integration
Operator's Income	168870.65	191663.34	157913.34	246632.09
Opportunity cost of family operating capital	11769.10	11769.1	13000	14500
Operator's Labour and Management Income	84431.74	179894.24	144913.34	232132

Source: Farm survey, 2024

We got that opportunity cost of operator's labour (9000/months X Six months/yr): BDT 54000

Estimation of Management Income

Management income is the Total Managerial Income from the farm. Yearly, the Operator's Labour and Management Income of the farm is calculated previously as BDT 84431.74. Besides, the Opportunity cost of operators labour of the farm is calculated as the value of BDT 54000. For calculating the management income; we used the following formula ---

[Management Income = (Operator's labour & Management Income - Opportunity cost of operators labour)]

The management income is calculated in the table-8 as BDT 30431.74 in the business-as-usual model. Besides, in the three models i.e. cow-dung stick, vermi-compost and bio-gas integration model; the operator's income is BDT 71894.24, 39913.34 and 124132.00 (table-8)

Table-8: Management Income from Livestock Farming Models

Livestock Farming Models	Business-as-usual model	Business Integration Models		
		Cow-dung stick Integration	Vermi-compost Integration	Bio-gas Integration
Operators labor and Management Income	84431.74	179894.24	144913.34	232132
Opportunity cost of operators labor	54000	108000	108000	108000
Management Income	30431.74	71894.24	39913.34	124132

Source: Farm survey, 2024

Comparison of Management Income among various models of Livestock Farming

Table-9 showed that the Management Income from business-as-usual model is BDT 30431.74;

Whereas, it is BDT 71894.24, 39913.34, 124132 respectively in the integration of cow-dung stick, vermi-compost and bio-gas model. Over management income, the net value addition from the cow-dung stick integration, vermi-compost integration and bio-gas integration models are BDT 41462.49, 9481.59; 93700.25 respectively -- which is excess by 42%, 76%, 24% of Management income of business-as-usual model. Thus, it can be said that the Integration of business model can significantly increase the economic profitability of cattle farming.

Table-9: **Comparison of Management Income among various models of Livestock Farming**

Livestock Farming Models	Business-as-usual Model	Business Integration Models		
		Cow-dung stick Integration	Vermi-compost Integration	Bio-gas Integration
Management Income	30431.74	71894.24	39913.34	124132
Difference of Income more than the BaU Model	---	41462.49	9481.59	93700.25
Changes of percentage	---	42%	76%	24%
More income in percentage	---	58%	24%	76%

Source: Farm survey 2018

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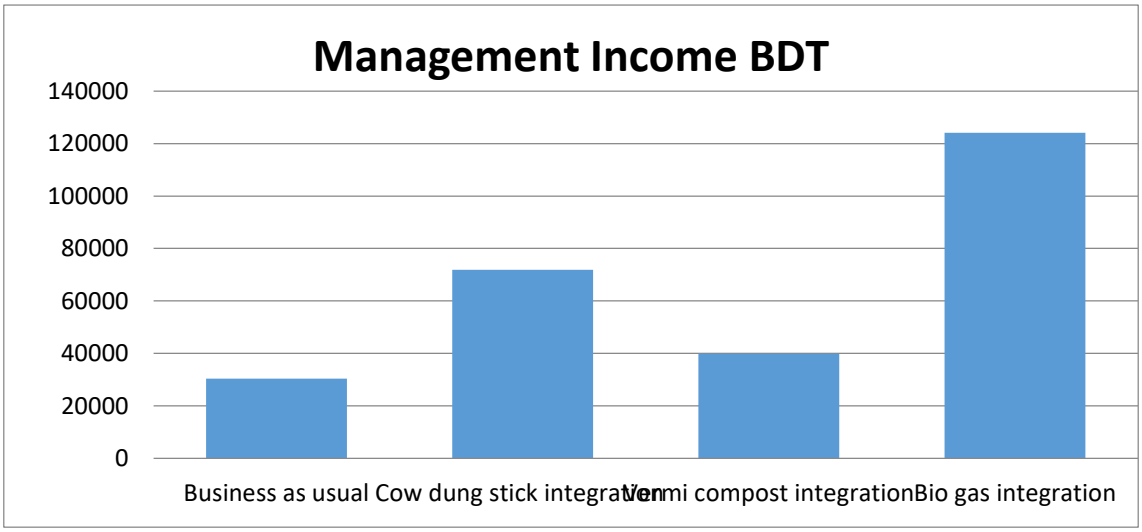

Fig-2: Showing Variations in Management Income of Various Models of Cattle Farming Over the Business-as-Usual Model

3.3. Farmers' Perception of Livestock Multi-functionality

Farmers demonstrated a strong appreciation for the diverse roles of livestock. At the farm level, **soil fertility** was the most highly recognized contribution, with 85% of farmers either agreeing (50%) or strongly agreeing (35%) with its importance. Its function as a **risk buffer** was also highly valued, with 60% agreement (30% agree, 30% strongly agree).

At the societal level, **food and nutrition** security were a paramount contribution, with 80% of farmers agreeing or strongly agreeing. Again, **soil fertility** was perceived as a major societal benefit, with 80% agreement (55% strongly agree, 25% agree). These perceptions underscore that farmers view livestock as an integral component of their livelihood and the broader community's well-being, far beyond a simple commodity.

3.4. Challenges Faced by Cattle Farmers

The study identified distinct challenges for BaU and integrated farming systems, as ranked by the Problem Facing Index (PFI) in Table-10.

For farmers practicing the BaU model, **disease occurrence** was the most severe constraint (PFI: 310), followed by the **high price of feeds** (PFI: 285). In contrast, farmers who had adopted integrated models reported different primary challenges.

Bad odor from manure management was the top-ranked problem (PFI: 260), with the **non-availability of skilled labor** being the second most significant obstacle (PFI: 250).

Table-10. Ranking of Major Challenges Faced by Cattle Farmers (PFI Score)

Challenges And Obstacles	Severe problem	Moderate problem	Low problem	No problem
Grazing land	60	30	20	10
Disease occurrence	90	15	10	0
High price feed	70	30	15	5
Price fluctuation	65	35	10	20
Cow dung management	65	35	15	5
Non availability of labour	50	40	20	10
Bad odor	60	35	15	10
Uncontrollable rainy season	40	40	20	0
Low percent of bio-gas	40	30	20	10

Source: Calculated from Field Survey, 2024. Maximum possible score = 360 (120 respondents * 3)

Hence, the major challenge is the disease occurrence and minor problem is the availability of grazing land; these two major and minor problems have scored of 310 and 260 out of 480.

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4. DISCUSSION

The study's findings reveal that integrating non-conventional by-product utilization transforms cattle farming from a traditional subsistence activity into a significantly more profitable enterprise. The remarkable increase in Net Farm Income (47.51%) and Management Income (76%) through biogas integration confirms that valorizing "waste" such as manure provides a powerful economic incentive for farmers (Talukder & Taj Uddin, 2000). This aligns with circular economy principles and demonstrates a practical, market-driven approach to sustainable agriculture. The additional income can enhance household resilience, enabling farmers to invest in better nutrition, education, and farm inputs.

Farmers' strong perception of livestock's multi-functional roles, particularly in enhancing soil fertility, is a critical finding. This indigenous knowledge aligns with scientific evidence on the benefits of organic manure for improving soil structure and nutrient content. This shared understanding provides a solid foundation for agricultural extension services to promote integrated systems not just for economic gain, but also for their ecological benefits, such as reducing the reliance on costly and environmentally damaging chemical fertilizers (Pell et al., 2010). The recognition of livestock as a risk buffer further highlights its role in the livelihood security of poor households, acting as a living asset that can be liquidated during emergencies.

The challenges identified point to the need for tailored support strategies. For traditional systems, the high PFI scores for disease and feed costs highlight deep-seated systemic issues that constrain the entire livestock sector in Bangladesh (Rahman and Rahman, 1991). Strengthening veterinary services, improving access to vaccines, and promoting the cultivation of local, high-quality fodder are essential interventions. For the more innovative integrated systems, the emergence of challenges like bad odor and labor shortages suggests that technology adoption must be accompanied by technical training on proper management (e.g., biogas plant maintenance to control odor) and the development of labor-saving tools. These "second-generation" problems are common during the scaling of new technologies and must be addressed to ensure their long-term success and adoption (Vandamme et al., 2010).

5. CONCLUSION AND RECOMMENDATIONS

This study concludes that multi-functional livestock farming, when integrated with non-conventional by-product utilization, is a highly profitable and sustainable pathway for rural development in coastal Bangladesh. The valorization of cow dung through biogas, vermicompost, and fuel stick production significantly boosts household income, enhances food and nutrition security, and contributes to environmental objectives like improved soil health and climate change mitigation.

Despite the clear benefits, adoption is hindered by both traditional constraints (disease, feed costs) and emerging challenges related to new technologies (odor, labor). Based on these findings, the following policy recommendations are proposed

1. Promote Awareness and Training: Launch extension programs to increase mass consciousness about the economic and environmental benefits of livestock multi-functionality, with a focus on by-product management.

2. Enhance Access to Finance: Provide soft loans and financial incentives through government and non-government channels to help smallholders invest in technologies like biogas plants and vermicomposting units.

3. Strengthen Veterinary and Support Services: Improve the delivery of veterinary services, including mobile clinics, to combat disease outbreaks. Support should also be provided for the promotion of local fodder cultivation and unconventional feed resources to reduce costs.

4. Develop Market Linkages: Improve marketing facilities for both primary livestock products (milk) and value-added by-products to ensure farmers receive fair prices.

5. Addressing these areas will help unlock the full potential of the livestock sector, making it a more resilient, profitable, and environmentally sustainable cornerstone of the rural economy in Bangladesh.

6. DECLARATIONS

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Competing Interests

The authors have declared that no competing interests exist.

Authors' Contributions Salim Ahmed designed the study, managed the data collection, performed the data

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analysis, and wrote the first draft of the manuscript. Other Authors, Mohammad Fakhrul Alam & Shampa Roy managed the literature searches and contributed to the discussion section and socio-economic analysis. Prof. Dr. Fakir Azmal Huda contributed to the methodology and critically reviewed the manuscript. All authors read and approved the final manuscript.

Consent

All authors declare that written informed consent was obtained from all participating farmers for their participation in this study and for the publication of aggregated data.

Ethical Approval

All authors hereby declare that all procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

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Ethnomedicinal plants used for gastro intestinal disorders by the local people of Brahmanbaria, Bangladesh

Tahmina Haque[a*], Mohammad Zashim Uddin[a]
[a]Department of Botany, University of Dhaka, Dhaka-1000, Bangladesh.

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ABSTRACT

The present research documented the ethnomedicinal plants used by the local people of Brahmanbaria, Bangladesh to treat gastro intestinal disorders in their daily life. Ethnomedicinal data were collected in between June 2018 to June 2019 from 265 local people using mainly key informant's interview. Citation frequency and Fidelity level values were calculated for claimed their ethnomedicinal knowledge to estimate their healing potentials. A total of 61 ethnomedicinal plants were used against gastro intestinal disease category from 40 families. Mimosaceae was the most predominant family. The most cited plant species were *Litsea glutinosa*, *Centella asiatica*, *Holarrhena antidysenterica*, *Clerodendrum viscosum*, *Portulaca oleracea*, *Mangifera indica*, *Paederia foetida* and *Phyllanthus reticulatus.* Among the most cited plants, all were presented 100% Fidelity level except *Centella asiatica* and *Pithocellobium dulce.* This study contributes to record a database of ethnomedicinal plants used in gastro intestinal disease in Brahmanbaria. Plant species with related uses can be subjected to further ethno-pharmacology studies to find active compounds for the new drug candidates.

1. Introduction

Gastrointestinal disorders are cited more frequently in developing country where poor sanitation practices are more common. According to estimates of World Health Organization (WHO), gastrointestinal disorders caused nearly 1 million adult deaths worldwide during 2019 where diarrhea alone was responsible for 370,000 deaths in children under the age of 5 years. The most common gastrointestinal disorders are diarrhea, dysentery, constipation, abdominal inflammation etc. It is reported that digestive system disorders particularly diarrhea, was the fifth leading cause of global mortality, as approximately 100 million people died worldwide in 2012 from these types of disorders (WHO, 2014). Asia and lower-middle-income countries had notably higher case numbers than other regions (Zhao *et al*., 2025). Bangladesh has a high risk of diarrheal mortality and morbidity in the South Asian region. The prevalence of diarrhea in Bangladesh declined from 7.05% in 2006 to 3.91% in 2012–13, but then increased to 8.78% in 2019. Most of the people of native region are depends on plant based medicine for their primary healthcare treatment. There are more than 5000 angiosperm species (Khan and Huq 1975) in Bangladesh. Only 750 plant species have been documented as medicinal values (Ahmed *et al*., 2008 & Yusuf *et al*., 2009). Many medicinal Plants has been widely used by many people without documentation for preservation and scientific study. The present study is designed to document the ethnomedicinal uses of plants of Brahmanbaria district to find out the culturally important medicinal plants for cure of illnesses related to gastrointestinal disease.

2. Methodology

Ethnomedicinal plants documentation

Brahmanbaria is a district in east-central Bangladesh lies between 23°57′10″ and 23.9528° N latitude and between 91.07′00″ and 91.1167° E longitudes. It is a part of the Chottogram Division. Fig. 1 is showing study area of Brahmanbaria district. Ethnobotanical study was carried out from June 2018 to June 2019 following the standard guidelines for ethnobotanical survey (Alexiades, 1996 and Chambers, 1994). Scientific name, local name, family name, habitat, parts used, use formularies of each plants have been recorded following standard methods (Martin, 2004). Voucher specimens for each medicinal plant have been collected and processed using standard herbarium techniques (Hyland, 1972 & Alexiades, 1996) and have been deposited at Dhaka University Salar Khan Herbarium, Department of Botany, University of Dhaka.

***Corresponding Author:** Tahmina Haque
Email Address: tahmina066@gmail.com

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Citation frequency

Calculation of citation frequency (CF%) is a way to determine the most useful plants. CF values are useful to determine most common medicinal plants in study area. CF values of medicinal plants were estimated using the formula: (number of people interviewed citing species/ total number of people interviewed) × 100 (Rahmatullah *et al.*, 2011).

Fidelity level

The fidelity level (FL) value is useful for identifying the informants most preferred species in use for treating certain ailments (Firedman *et al.*, 1986). The fidelity level (FL), the percentage of informants claiming the use of a certain plant species for the same major purpose was calculated for the most frequently reported diseases or ailments as: FL (%) = (Np / N) × 100; Where, Np = number of informants that claim a use of a plant species to treat a particular disease; N = number of informants that use the plants as a medicine to treat any given disease.

3. Results

In the present study, Brahmanbaria district, Bangladesh is chosen for data collection. Fig. 1 showing the study area of Brahmanbaria district. A total of 61 plant species from 40 families used by the local people have been recorded with their medicinal use formularies. Scientific name, local name, family name, habitat, ailments, parts used, treatment mood and Citation frequency (CF%) of each plants have been shown in Table 1. Table 2 is showing the Fidelity level (FL) of most cited ethnomedicinal plants.

Recorded ethnomedicinal plant species in the Brahmanbaria district is the indication of huge diversity of medicinal plants and their uses. Among the 40 families, Mimosaceae was best represented in terms of the number of species, followed by Fabaceae, Cucurbitaceae and Verbenaceae (Fig. 2). In case of Habitat distribution 35% has been represented by trees, 32% by herbs, 18% by shrubs and 15% by climbers (Fig. 3). Most of the ethnomedicinal plants were collected from wild habitat. Among the plant parts used, leaf was the most frequently used plant parts (44%) followed by Fruit (18%), Bark (11%), Seed (6%), Whole plant (3%) Tuber (3%) and others (5%) including flower, stem, rhizome (Fig. 4).

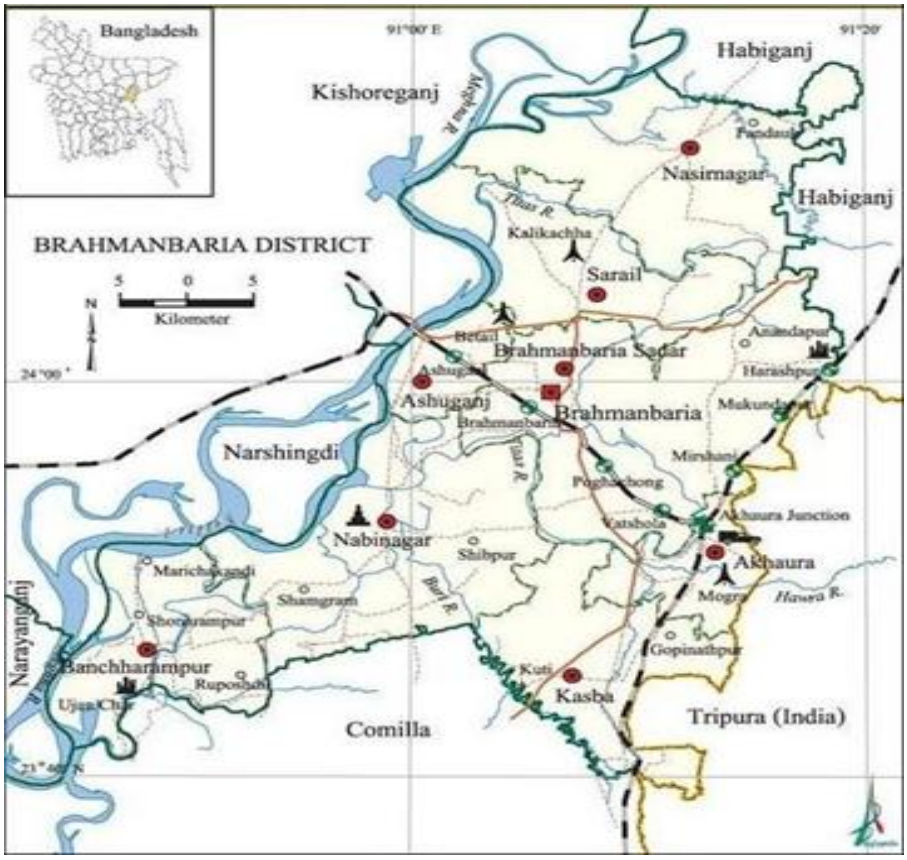

Fig. 1: Study area of Brahmanbaria district.

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Table-1: Ethnomedicinal data of medicinal plants and their uses. (T-Tree, S-Shrub, H-Herb, C-Climber, Wp-Whole plant).

Scuientific name	**Local name**	**Family**	**Habitat**	**Ailments**	**Parts use**	**Treatment mood**	**Citation frequency (CF%)**
Acacia nilotica TH-248	Babla	Mimosaceae	T	Diarrhea	Bark	Decoction taken internally twice daily	2.64
Albizzia lebbeck (L.) Benth TH-249	Sirish koroi	Mimosaceae	T	Inflammation	Bark	One or two table spoon powder mixed with one glass of water which taken internally	1.13
Allium sativum (L.) TH-117	Rosun	Liliaceae	H	Abdominal pain	Bulb	Paste taken internally with boiled rice	1.13
Amorphophallus paeoniifolius (Dennst.) Nicolson TH-275	Ol kochu	Araceae	H	Diarrhea	Tuber	Decoction taken internally	1.13
Antigonon leptopus Hook. et Arn.TH-247	Anantamul	Polygonaceae	C	Diarrhea	Root	Decoction taken internally	0.37
Bacopa monnieri (L.) TH-261	Brammi	Scrophulariaceae	H	Stomachache	Leaf	Juice taken internally	1.13
Barringtonia acutangula (L.) Gartn. TH -305	Eijol gach	Lecythidaceae	T	Gastric	Leaf	Juice taken internally	0.75
Basella alba (L.) TH-114	Puilata	Basellaceae	C	Constipation	Twig	Cooked with oil & salt which taken internally	1.13
Boerhaavia diffusa (L.) TH-14	Punarnabba	Nyctaginaceae	S	Digestion	Leaf	boiled leaf taken internally	0.75
Celosia cristata (L.) TH-278	Morogful	Amaranthaceae	H	Diarrhea	Leaf	Juice is prepared by mixing salt and sugar and taken internally every day until	0.75

						disease is cured	
Centella asiatica (L.) Urban TH-02	Tunimankoni	Apiaceae	H	Dysentery	Wp	Juice or paste taken internally until cure	24.5
Centella asiatica (L.) Urban, TH-02	Tiamoni	Apiaceae	H	Stomach ache	Leaf	Paste taken with Boiled rice	5.28
Chromolaena odorata (L.) R.M.King & H.Rob. TH-276	Assamlata	Asteraceae	C	Dysentery	Leaf	Juice is taken internally	0.37
Citrus aurantifolia (Cristm. & Panzer) Swingle	Kangogilebu	Rutaceae	S	Laxative	Fruit	Juice mixed with boiled water & taken internally	3.01
Clerodendrum viscosum Vent, TH-153	Vetvedi	Verbenaceae	S	Diarrhea	Leaf	Extract internally taken by children	16.2
Coccinea cordifolia (L.)Cogn. TH-03	Telakucha	Cucurbitaceae	C	Appetizer	Leaf	Paste taken with Boiled rice	1.88
Crataeva magna (Lour.) DC. TH-32	Barunpata	Capparaceae	T	Diarrhea	Leaf	Juice taken internally	0.37
Crotalaria pallida Ait. TH-246	Jhunjune	Fabaceae	S	Digestion	Root	Extract taken Internally	0.75
Cucumis sativus (L.) TH-268	Sasha	Cucurbitaceae	H	Gastric	Fruit	Taken internally	0.75
Cucurbita maxima Duch TH-303	Mistikumra	Cucurbitaceae	C	Laxative	Fruit	Boiled with salt & taken internally	0.75
Cuminum cyminum TH-302	Zira	Apiaceae	H	Gastric	Seed	Powder mix with water & taken internally	0.37
Dalbergia sissoo Miq TH-104	Sissoo	Fabaceae	T	Dysentery	Leaf	One spoon of juice taken internally two times daily for seven days	9.06
Echinopsis peruviana (Britton & Rose) TH-134	Hiz gach	Cactaceae	H	Constipation	Aerial part	Decoction taken internally every	0.37

						morning for several days	
Eryngium foetidum (L.) TH-63	Rashnapata/Boro Dhania	Apiaceae	H	Appetizer	Wp	Juice Taken internally	0.75
Ficus benghalensis (L.) TH-166	Botgach	Moraceae	T	Dysentery	Root	Juice taken internally	0.37
Gloriosa superba (L.) TH-287	Ulatchandal	Liliaceae	C	Stomachache	Tuber	One spoon of extract taken internally	0.37
Hibiscus rosa sinensis (L.) TH-163	Roktojaba	Malvaceae	S	Dysentery	Leaf	Mashed & taken with rice	1.88
Hibiscus sabdariffa (L.) TH-58	Mestapata	Malvaceae	H	Appetizer	Fruit	Boiled with water & salt than taken internally	0.37
Holarrhena antidysenterica (L.) Wall. ex Decne. TH-148	Kuruz	Apocyanaceae	T	Dysentery	Leaf	Juice of fresh leaf taken internally at morning	21.5
Hyptis suaveolens (L.) Poit. TH-38	Tokmai	Lamiaceae	H	Constipation	Seed	Juice taken internally	0.75
Ipomoea batatas (L.) Lamk. TH-107	Mistialu	Convulvulaceae	C	Stomach ache	Leaf	Paste taken with boiled rice	2.26
Justicia gendarussa Burm. f. TH-176	Jogmardon	Acanthaceae	S	Stomach ache	Leaf	Juice taken internally	0.37
Lannea coromandelica (Houtt.) Mers. TH-132	Zigar gach	Anacardiaceae	T	Dysentery	Bark	Extract taken internally for three days	0.37
Lantana camara (L.) TH-168	Chutra pata	Verbenaceae	S	Abdominal pain	Leaf	Decoction taken internally	0.75
Lippia alba (Mill.) Briton *et* Wilson TH-138	Motka	Verbenaceae	H	Diarrhea	Leaf	Juice taken 2/3 times everyday until disease is cured	10.9
Litsea glutinosa (Lour.) Robinson, TH-08	Menda	Louraceae	T	Dysentery	Leaf	Mashed with water than one glass taken internally	34.7

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						in morning & evening until cure	
Ludwigia ascendens TH-252	Mulsi	Onagraceae	H	Dysentery	Leaf	Extract taken Internally	0.75
Ludwigia prostrata (Roxb.) TH-187	Nakful	Onagraceae	H	Diarrhea	Leaf	Cooked & taken internally	0.37
Lycopersicon lycopersicum (L.) Britton & Brown TH-128	Tometo	Solanaceae	h	Appetizer	Fruit	Ripe fruit taken as salad	0.75
Mangifera indica (L.)sw, TH-133	Aam	Anacardiaceae	T	Diarrhea	Leaf	Chewed young leaves	13.2
Melastoma malabathricum (L.) TH-185	jonglitezpata	Melasomataceae	S	Diarrhea	Leaf	decoction taken internally	1.13
Mesua ferra (L.) TH-295	Nageshor	Clusiaceae	S	Dysentery	Leaf/ Flower	Decoction taken internally in empty stomach until disease is cured	1.50
Mimosa pudica (L.) TH-35	Lajonti	Mimosoideae	H	Diarrhea	Root	Juice taken internally	4.52
Moringa oleifera lamk, TH-26	Sajna	Moringaceae	T	Diarrhea	Leaf	Fried leaf eaten with rice twice a day for 3 days	0.37
Murraya paniculata (L.) Jack TH-22	Kaminiful	Rutaceae	T	Stomachache	Leaf	Juice taken internally	1.13
Musa paradisiaca (L.) TH-67	Attya kola	Musaceae	T	Dysentery	Fruit	Crusted raw fruit taken orally with rice until cure	6.41
Paederia foetida (L.) TH-30	Padrapata	Rubiaceae	C	Diarrhea	Leaf	Paste taken internally with rice	11.6
Pasplum scrobiculatum (L.) TH-123	Dhan durba	Poaceae	H	Diarrhea	Wp	Tied around west until cure	3.39
Phyllanthus embelica (L.) TH-05	Amloki	Euphorbiaceae	T	Appetizer	Fruit	Crusted dry fruit	13.2

						taken internally	
Phyllanthus reticulatus (Poir.) TH-61	Sitki	Euphorbiaceae	S	Diarrhea	Stem & Leaf	One spoon of extract taken internally for child	4.90
Pithecellobium dulce (Roxb.) Benth, TH-231	Moccasarif gach	Mimosaceae	T	Stomachache	Bark	Decoction is taken internally twice daily	8.67
Pithecellobium dulce (Roxb.) Benth, TH-231	Moccasarif gach	Mimosaceae	T	Diarrhea	Bark	Boiled in water which is taken two times daily	3.01
Polygonum hydropiper (L.),TH-88	Bishkatali	Polygonaceae	H	Dysentery	Leaf	Juice taken internally	1.13
Portulaca oleracea (L.) TH-289	Nontashakh	Portulaceae	H	Dysentery	Wp	Decoction is given to children	13.5
Psidium guajava (L.), TH-109	Peara	Myrtaceae	T	Diarrhea	Leaf	Juice of young leaves taken internally	9.43
Rosa damascena Mill. TH-129	Golap	Rosaceae	S	Digestion	Flower	Juice taken internally	0.75
Santalum album (L.) TH-272	Chandon gach	Santalaceae	T	Gastric	Bark	Grinded to form powder which is taken internally	0.75
Syzygium jambos (L.) Alston TH-161	Golapjam	Myrtaceae	T	Appetizer	Fruit	Taken internally as necessary	3.77
Tectona grandis (L.) TH-277	Kathgach	Verbenaceae	T	Stomachache	Bark	Decoction of young stem bark is mixed with leaf paste of *Centella asiatica* which is taken internally	1.50
Terminalia arjuna (Roxb. ex DC.) Wight & Arn.TH-01	Aurjun	Combretaceae	T	Gastric	Fruit	Powder of bark mix with water	1.13

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						& taken internally	
Trigonella foenum-graecum (L.) TH-101	Methi	Fabaceae	H	Gastric	Seed	Fried & taken internally	0.37
Vigna unguiculata (L.) Walp. TH-253	Barbati	Fabaceae	C	Laxative	Fruit	Paste taken internally	0.75

Table 2. Fidelity level (FL) of most cited ethnomedicinal plants.

Scientific name	**Np**	**N**	**FL(%)**
Litsea glutinosa (Lour.) Robinson, TH- 08	92	92	100
Centella asiatica (L.) Urban TH-02	65	74	87.84
Holarrhena antidysenterica (L.) Wall. *Decne.* TH-148	57	57	100
Clerodendrum viscosum Vent, TH-153	43	43	100
Portulaca oleracea (L.) TH-289	36	36	100
Mangifera indica (L.) TH-133	35	35	100
Phyllanthus embelica (L.) TH-05	35	35	100
Paederia foetida (L.) TH-30	31	31	100
Lippia alba (Mill.) Briton *et* Wilson TH-138	29	29	100
Psidium guajava (L.) TH-109	25	25	100
Pithecellobium dulce (Roxb.) Benth, TH-231	23	31	74.19
Musa paradisiaca (L.) TH-67	17	17	100

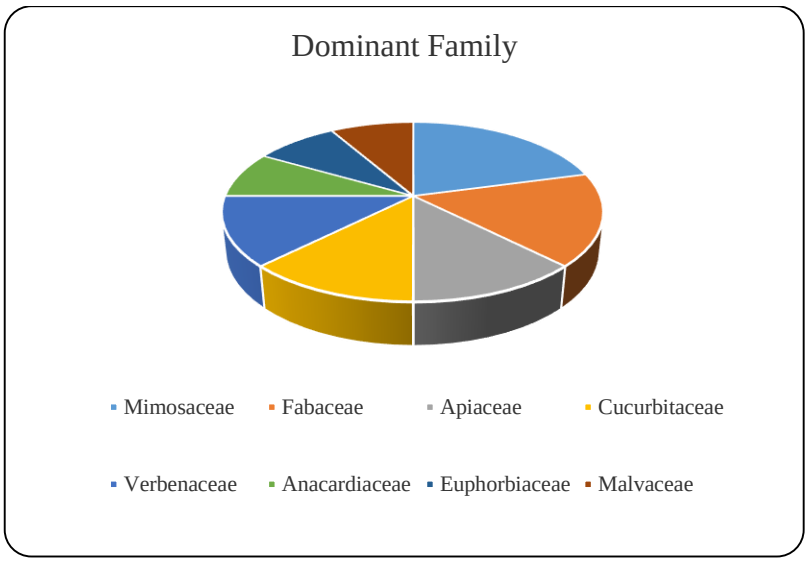

Fig. 2. Number of useful ethnomedicinal plant species per family from the study area.

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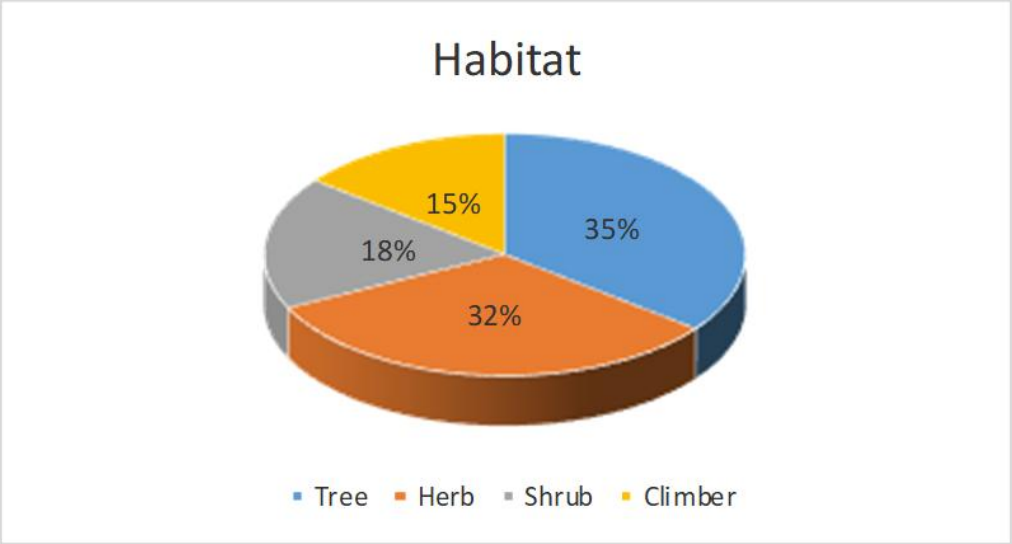

Fig. 3. Diversity of habits of medicinal plants.

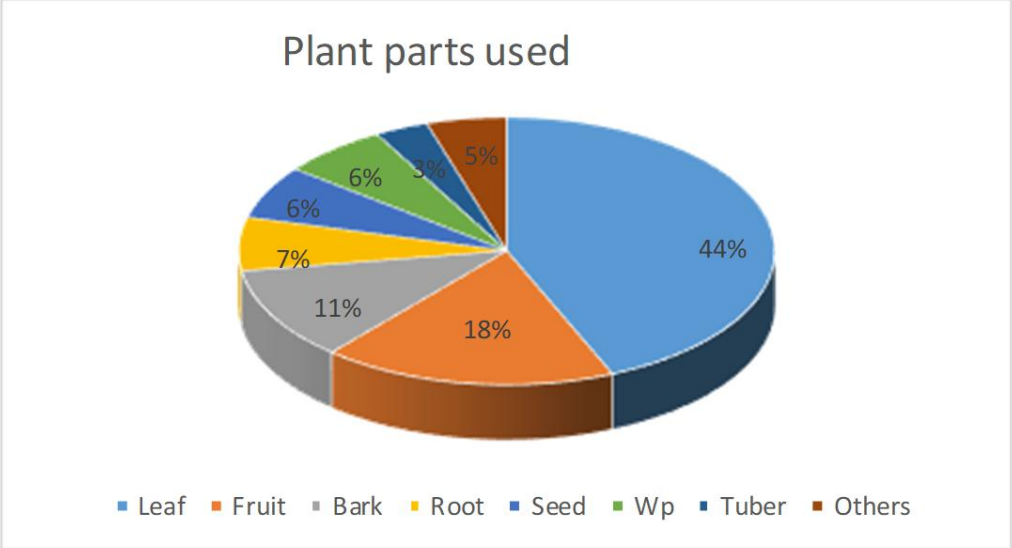

Fig. 4. Consensus in the plant parts used in the study area.

A total 63 actual use records were registered by piloting the 265 interviewed with key informants and local residents. The ailment for which there was the most frequently reported was diarrhea and dysentery whereas abdominal pain, appetizer, constipation, laxative, digestion, diuretic and gastric were also common. According to citation frequency most cited plant species in the gastrointestinal diseases were *Litsea glutinosa* (34.7%), *Centella asiatica* (24.5%), *Holarrhena antidysenterica* (21.5%), *Clerodendrum viscosum* (16.2%), *Portulaca oleracea* (13.5%), *Mangifera indica* (13.3%), *Phyllanthus reticulatus* (13.2%) and *Paederia foetida* (11.6%). Most of the ethnomedicinal plants showed 100% fidelity level. *Centella asiatica* showed 87.8% fidelity level and *Pithocellobium dulce* had 74% fidelity level (Table-2).

4. Discussion

In the present study 61 ethnomedicinal plant species from 40 families with 63 uses were mentioned by conducting 265 interviews at nine upazila of Brahmanbaria district from the local people of Brahmanbaria, Bangladesh. The results exposed the ethnomedicinal plants including family, habitat, use parts and use formularies focuses on gastrointestinal disease category. Among the 40 families, Mimosaceae was most represented in terms of the number of species, followed by Fabaceae, Cucurbitaceae and Verbenaceae. The family Fabaceae reportedly has the

highest number of species more than any other plant family in the world (Chandra, 2005 & Haque *et al*., 2014). A similar trend was also observed that trees and herbs were the most used growth form of ethnomedicinal plants in the study area which also found in other investigation (Haque *et al*., 2017). Leaves are the most commonly used plant parts for the preparation of the medicine (Fig. 3). The reason why leaves were used mostly is that they are collected very easily than underground parts, flowers and fruits. On the other hand, leaves are active in photosynthesis and produce metabolites (Ghorbani, 2005 & Tangjitman *et al.*, 2015).

The most common ailment was diarrhea and dysentery in the study area possibly showed that this ailment is common in the study area due to poor sanitation in the region. The local people of Brahmanbaria also used the plant species against ailments such as abdominal pain, appetizer, constipation, laxative, digestion, diuretic and gastric. Therefore, this indicates that the gastrointestinal diseases are common in the study area and local people prefer to use plants to get remedy. Usually rural people collect medicinal plants from their backyards and surroundings as well as use them to treat these diseases. Most of the treatment formularies inherited by elder person of the family and from local medicine men (kabiraj) or personal experience.

Ethnomedicinal plant having highest CF value and FL value (highest citation frequency) of the present survey which is discussed here comparing with the other related literature. The species accountable for the high CF and FL value for gastrointestinal diseases were *Litsea glutinosa, Centella asiatica, Holarrhena antidysenterica, Clerodendrum viscosum, Portulaca oleracea, Mangifera indica, Paederia foetida* and *Phyllanthus reticulatus.* Among them *Litsea glutinosa* (CF= 34.7% and FL=100%) was the best used medicinal plant in the study area for the cure of diarrhea and dysentery. The ethanol and aqueous extracts of leaves showed antibacterial activity (Haque *et al*. 2022). The bark has effective antibacterial activities against *Pseudomonus aeroginosa, Staphylococcus aureus* and *E.coli*. The bark showed also antifungal activities against *Aspergillus fumigates* & *Candida albicans* (Hosamath, 2011). Uddin (2014) suggest that *Litsea glutinosa* might be used for the development of new, cheap, effective, and eco-friendly herbal formulations for health-care management but the illegal and unsustainable collection of bark from this tree by the local crude drug traders considered as major causes of its depletion from nature. The second highest scored plant was *Centella asiatica* (CF=24.5% and FL= 87.8%) used for the treatment of dirrhoea and stomachache. This plant is also used for treatment of various diseases like dysentery by the Bauri tribe (Das *et al*., 2013). *Dalbergia sissoo* used for dirrhoea in present study, also reported in Feni districts with a high citation (Uddin *et al*., 2015). These result might confirm that notable ethno medicinal plants have a potential effect on treating gastrointestinal disorders. So these Plants should be further investigated for updated their validation scientifically.

5. Conclusion

Gastrointestinal disorders are one of the most common types of ailments affecting humans. Several ethnomedicinal studies revealed that the use of medicinal plants by traditional people against digestive system disorders is a common practice throughout the world. The present study is the first time effort to documented gastrointestinal disease activity of ethnomedicinal plants of Brahmanbaria district. The results indicated that the study area is rich in ethnomedicinal plants and diversity of knowledge of medicinal uses in the primary health care. The ethnomedicinal plants secured high CF and FL values such as: *Litsea glutinosa, Centella asiatica, Holarrhena antidysenterica, Clerodendrum viscosum, Portulaca oleracea, Mangifera indica, Paederia foetida* and *Phyllanthus reticulatus* should be scientifically investigated. Ethnomedicinal plants have been used in Brahmanbaria but most of them have not been studied and documented. Therefore, the present study successfully recorded and documented the uses of ethnomedicinal plants focusing on gastrointestinal disease category. The present information on these ethnomedicinal plants, which have high CF and FL values, may serve as the baseline data to initiate further research for the discovery of new compounds to the remedy of gastrointestinal diseases.

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7. Conflict of interest

The authors declared there is no conflict of interest.

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Review on the Book 'The Sealed Nectar' (اَلرَّحِيْقُ الْمَخْتُوْمُ- -Al-Rahiiq Al-Makhtuum). Written by Safiur Rahman Mubarakpuri. Published by Darussalam Publishers (English edition). First published: 1979.

Md. Shamsul Alam [a] *, Dr. Muhammad Al-Amin[b], Md. Mizanur Rahman[b]
[a] *Islamic Arabic University, Dhaka, Bangladesh*
[b] *Rajuk Uttara Model College, Dhaka, Uttara Model Town, Dhaka-1230, Bangladesh*

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Introduction

The Sealed Nectar is an award-winning biography of Prophet Muhammad (PBUH), originally written in Arabic by Shaykh Safiur Rahman Mubarakpuri (May Allah shower mercy on him). The book won the first prize in a global competition on the life of the Prophet (PBUH) organized by the Muslim World League in 1979. It is now available in many languages, including English and Bangla. The book covers the Prophet's (PBUH) life in a chronological, well-researched, and authentic manner, relying on authentic sources from classical Islamic scholarship.

Review: *The Sealed Nectar* by Safiur Rahman Mubarakpuri (May Allah shower mercy on him) is one of the most celebrated and widely accepted biographies of Prophet Muhammad (PBUH). Originally this book was written in Arabic. Arabic name of the book is (-اَلرَّحِيْقُ الْمَخْتُوْمُ --Al-Rahiiq Al-Makhtuum). To our knowledge, it has been translated into 15 languages so far. These are: English, Urdu, Bangla, Turkish, Malay, French, Spanish, Persian, Hindi, Tamil, Kannada, Telugu, Hausa, Swahili and Russian. The book won the first prize in the 1979AD/1396 AH, selected from 171 manuscripts written in various languages worldwide competition on the biography of the Prophet (PBUH) organized by the Muslim World League (Rabeta al-Aalam al-Islami) in Makkah. We have gone through the Arabic text and English translation of the book and have found that the translation has been completely originalized. We will mainly discuss focusing on the English translation entitled *The Sealed Nectar*.

Safiur Rahman Mubarakpuri (1943–2006), an Indian scholar from the Salafi school of thought, was a prolific writer and educator affiliated with various Islamic institutions in India and Saudi Arabia. His contribution to Islamic literature, especially in the field of *Siirah* (Prophetic biography), remains unparalleled. His work combines narrative clarity with academic rigor, making it accessible to both scholars and readers. Mubarakpuri's deep commitment to authentic sources and methodological discipline is reflected in this award-winning text.

The book is divided into numerous chronological chapters that trace the life of Prophet Muhammad (PBUH) from pre-Islamic Arabia to his death.

A concise chapter-by-chapter Synopsis

Here's a concise chapter-by-chapter synopsis of ***The Sealed Nectar*** **(Al-Rahiiq al-Makhtuum):**

Pre-Islamic Context & Early Life

Chapters 1, 2, 3 and 4 set the stage with pre-Islamic Arabia—geography, tribal divisions, social norms, religious practices, and Muhammad's lineage, childhood, marriage with Khadījah, adulthood, protection under guardians, the reconstruction of the Kaʿbah, and his spiritual temperament just prior to prophethood.

***Corresponding Author:** Md. Shamsul Alam
Email Address: shamsulalam@du.ac.bd

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Gaining Nubuwat, Invitation & Meccan Period

Chapters 5, 6 and 7 cover the initial revelation in the Cave of Ḥirā, secret phase of preaching, the first believers, and the start of Quraysh's opposition.

Chapter 8 narrates the escalation to open preaching, the community's reactions, early migrations to Abyssinia, and memorable conversions like those of Ḥamzah (May Allah be pleased with him) and ʿUmar (May Allah be pleased with him).

Chapter 9 chronicles the social boycott, conspiracies, threats to the Prophet (PBUH), and Quraysh's tactics to suppress the message.

Chapter 10 describes the "Year of Grief"—the losses of Abū Ṭālib and Khadījah (May Allah be pleased with her) —and Muhammad's subsequent marriage to Sawdah (May Allah be pleased with her).

Expansion & Hijrah

Chapters 11, 12 and 13 explore factors that strengthened the Prophet's resolve, the spread of Islam outside Mecca, the Israʾ and Miʿrāj, and the pledges of al-ʿAqabah that paved the way for migration.

Chapters 14, 15, 16, 17, 18, 19 and 20 recount the Prophet's migration (Hijrah), the founding of the Medina community, the Constitution of Medina, alliances with Jewish tribes, and the build-up to pivotal battles like Badr and Uhud.

Battles, Politics & Community Building

Chapter 21 divides Medina-era events into three phases:

1.Internal strife and external hostilities culminating in the Treaty of Ḥudaybiyyah,

2.Stability leading to the Conquest of Mecca and outreach beyond Arabia,

3. Widespread acceptance of Islam through delegations and conversions, until the Prophet's death.

Final Years & Legacy

Chapters 22, 23, 24 and 25: Highlight the Tabūk expedition, Hunayn, and the Farewell Pilgrimage. The conclusion details the Prophet's final days, his illness, his passing in Rabīʿ al-Awwal 11 AH, and reflections on his character and enduring legacy.

Salient Feature of the Book

Each chapter of the book is meticulously sourced from classical texts such as *Siirah Ibn Hisham, Al-Waqidi, Al-Tabari*, *Sahiih al-Bukhari*, and *Sahiih Muslim*, among others. The chronological narrative aids comprehension and allows readers to follow the development of the Islamic message and the growth of the Muslim community in Arabian peninsula.

The book mentions the Quran and Sunnah in most of the situations of the prophet's life. Such as:

1.It mentions the devotion and absolute reliance of the prophet (PBUH) on Almighty Allah. *The Prophet* (PBUH) *used to pray to his Lord persistently day and night to come to their help the fierce engagement grew too. He again began to supplicate his Lord saying:*

"O Allah should this group (of Muslims) be defeated today, You will no longer be worshipped." He continued to call out to his Lord, streching forth his hands and facing al-Qiblah, until his cloak fell off his shoulders. He continued to call out to his Lord, stretching forth his hands and facing Al-Qiblah, until his cloak fell off his shoulders. Then Abu Bakr came, picked up the cloak, and put it back on his shoulders and said: "O Prophet of Allâh, you have cried out enough to your Lord. He will surely fulfill what He has promised you." (P.263).

Immediate was the response from Allâh, Who sent down angels from the heavens for the help and assistance of the Prophet and his Companions.

2. The book illustrates the last moments of prophet's life in a very significant way. For example:

On Wednesday, five days before he died, the Prophet's (PBUH) temperature rose very high signaling the severity of his disease. He fainted and suffered from pain. "Pour out on me seven Qirab (water skin pots) of various water wells so that I may go out to meet people and talk to them" he said. So, they seated him in a container and poured out water on him till he said, 'That is enough. That is enough." Then he felt well enough to enter the Masjid. He entered it with his head wrapped, sat on the pulpit and gave a speech to the people who were gathering together around him. He said: "He whom I have ever lashed his back. I offer him my back so that he may avenge himself on me. He whom I have ever insulted his honor, here I am offering my honor so that he may avenge himself." (P.551) Subhaanallah, How magnanimous he was! How benevolent he was!

Literary and Academic Merits

Mubarakpuri succeeds in presenting a balanced portrayal of the Prophet's life, combining historical fact with spiritual insight. His tone is respectful but not overly hagiographic, and he avoids exaggeration, hyperboling. He adheres closely to authenticated sources.

One of the greatest strengths of the book is its methodological transparency. The author distinguishes between weak and strong narrations, explaining his choices in referencing certain events. The extensive referencing and footnoting system lend credibility and academic integrity to the original work.

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Critical Observations
At this stage, we will add some considerable evaluative comments on the praiseworthy work from the several prestigious institutions and luminous scholars.

1.Islamic University of Madinah (Competition Jury)
In 1979, *Al-Rahiiq Al-Makhtuum* was awarded first prize in an international Siirah competition organized by the Muslim World League (Rabeta al-Aalam al-Islami).
171 manuscripts from scholars around the world were submitted, and this book was selected for its accuracy, clarity, methodical arrangement, and scholarly authenticity.
Jury's Evaluation was: "A Siirah work distinguished by academic rigor, comprehensive coverage, and ease of understanding." (Source: en.wikipedia.org)

2. Shaykh Ibn Baz – Former Grand Mufti of Saudi Arabia
Though there is no direct published quote, it is well known that Shaykh Ibn Baz supported and endorsed literature based on authentic sources. He is said to have praised *Al-Rahiiq Al-Makhtum* as a valuable contribution to Seerah literature, particularly useful for students and general Muslims alike. (Source: edrussalam.com)

3. Shaykh Muhammad Nasiruddin al-Albani (May Allah shower mercy on him) – Scholar of Hadith Science.
While Shaykh al-Albani didn't write a full review, he acknowledged that any Seerah book free of fabricated reports and based on authentic narrations is highly beneficial. Scholars in his circle recognized *Ar-Raheeq Al-Makhtum* as aligning with this standard.

4. Dr. Muhammad al-Areefi (May Allah protect him)**– Prominent Da'ee and Scholar**
He mentioned the book in his lectures as:
"A Siirah book that should be part of every Muslim's library—written in a way that engages the mind and heart while maintaining academic trustworthiness."

5. Islamic Scholars & Institutes Worldwide
Many universities and institutes across the Muslim world—such as Al-Azhar, Jamia Salafiyyah, and others—include *Al-Rahiiq Al-Makhtuum* in their curriculum or recommend it as:
"An ideal introductory book on Siirah, offering both narrative inspiration and academic structure."

Limitations and Constraints
While *Al-Rahiiq Al-Makhtuum* is widely praised, according to our knowledge some limitations are noticeable. Such as:

1.Sectarian Orientation: The book aligns with the Salafi interpretive tradition, which may not reflect the full diversity of Islamic thought. Certain dogma (Aqiidah) or historical interpretations might differ from those held by Sufi, Shi'i, or traditionalist Sunni scholars.

2.Lack of Analytical Depth: The book is largely descriptive, with limited engagement in socio-political analysis or critical historiography of contemporary period. Readers seeking more critical perspectives or thematic studies might find it lacking in that regard.

3.Minimal Use of Non-Islamic Sources: Mubarakpuri predominantly relies on Islamic primary sources and avoids Western academic literatures. While this ensures fidelity to the Muslim tradition, it limits the book's dialogue with contemporary *Siirah* studies or historical anthropology. On the other hand, we know that many orientalists have raised objections on various events of the Prophetic biography, if Mubarakpuri could refute and reply to them, that would be better and it could bring much more excellence in his book.
Finally we can say that the limitations and and weakness mentioned are purely perspective, but not fundamental.

Conclusion: *The Sealed Nectar* is a masterfully crafted biography that stands as a landmark contribution to Islamic literature. It is historically rich, dogmatically sound, and stylistically accessible. While it may not fulfill the demands of critical historiography in secular academia, it succeeds powerfully in its own domain—as a devotional yet reliable account of the Prophet's life. For readers seeking an authentic and faithful retelling of the *Siirah*, this book remains an indispensable resource. In fact, the book will persists in enthralling its readers with a perennial source of enlightment, insights, vision and invaluable resources resulting in tremendous and highly intellectual and judicious awakening in them. So, the book has added a new feather in the cap of critical prophetic siirah studies through its epoch-making style of presentation and postulation of diverse thoughts and ideas.