Vol. 6 (Iss. 1) 2025, pp. 886-894 African Journal of Empirical Research https://ajernet.net ISSN 2709-2607

# Quality Characteristics of Selected Zippers on the Ghanaian Market

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https://doi.org/10.51867/ajernet.6.1.75

## ABSTRACT

*Zippers play a vital role in the functionality and durability of apparel and accessories, yet they are often overlooked in favour of aesthetic considerations such as length and colour. The study employed Total Quality Management (TQM) Theory. TQM emphasizes continuous improvement, customer satisfaction, and quality control in manufacturing and production. This theory is relevant because it highlights the importance of producing zippers that meet industry standards, ensuring durability, strength, and functionality. This study employed a comparative experimental research design to evaluate the mechanical performance, colourfastness, and dimensional stability of five selected zipper brands (A, B, C, D and E) on the Ghanaian Market composed of metal and nylon materials. A total of 72 zippers were procured for the experiment. Mechanical strength was assessed based on top stop strength, puller attachment strength, and lateral strength, while colourfastness was tested under washing and rubbing conditions. Dimensional stability was measured in terms of percentage changes in length and width. The statistical software employed for the analysis of the data collected was the Statistical Package and Service Solution (SPSS) for Windows version 26. The results indicate that metal zippers exhibit superior mechanical strength, higher colourfastness ratings, and better dimensional stability than nylon zippers. ANOVA and t-tests at 0.05 alpha levels confirm that these differences are statistically significant ($p < 0.001$ and $p = 0.002$, respectively). Correlation analysis reveals strong positive relationships between colourfastness and mechanical strength, emphasizing the impact of material quality on zipper durability. The findings highlight the importance of selecting high-performance zippers for applications requiring enhanced durability and longevity. Metal zippers consistently outperformed nylon zippers in all measured parameters, showing greater resistance to tensile forces, superior colour retention, and minimal dimensional changes. The statistical analyses confirm these findings, with significant differences observed between the two material types. The correlation analysis further supports the interdependence between colourfastness and mechanical strength, indicating that zippers with better colour retention tend to have higher strength parameters. It was recommended that product designers should prioritize strength and durability by selecting zippers suitable for the intended application, ensuring robustness in high-stress environments. Quality control teams must focus on maintaining high wash and wet colourfastness in zippers, particularly for products exposed to frequent washing or outdoor conditions. To guarantee the selection of high-quality materials, standardized testing protocols should be implemented to evaluate zipper performance in real-world conditions.*

**Keywords:** Colourfastness, Fastener Durability, Garment Closure, Ghanaian Market, Wear Resistance, Zipper Performance

## I. INTRODUCTION

The performance of zippers, though often considered a minor component of clothing, plays a critical role in the overall functionality and usability of apparel and accessories. Zippers are pivotal in providing convenience, security, and ease of use, making them an essential element in both every day and specialized garments (Baker, 2007; Rasheed et al., 2017). They facilitate quick and secure fastening, which is integral to the design and practicality of clothing items, ranging from casual wear to high-performance gear. Globally, zippers have evolved significantly in terms of design, material, and technology (Nkrumah, 2015). Originally made from metal, modern zippers now come in various materials, including plastic and nylon, each offering different benefits in terms of durability, weight, and cost (Nissen, 2020). The technological advancements in zipper manufacturing have led to innovations such as waterproof zippers for outdoor gear and heavy-duty zippers for industrial applications (Umaru et al., 2016). These developments reflect broader trends in consumer preferences, where functionality and aesthetic appeal drive market choices.

Despite their importance, zippers have often been overlooked in academic literature and market research, particularly in the context of the Ghanaian market (Nkrumah, 2015). Most existing studies and product evaluations focus on broader categories like textiles and apparel without delving deeply into the performance of zippers. This oversight is significant given that zippers, while small, are crucial to the garment's performance and longevity. The importance of zippers in clothing has similarly been under-represented in research. Zippers are among the most often used fasteners in

Ghana's apparel industry because of their affordability and usability. Their durability and performance, however, are questioned. Zippers sold on the Ghanaian market for the clothing industry easily fail during use. The performance of zippers on imported clothing is superior to that of zippers marketed in Ghana. The quality of zippers available in the Ghanaian market is influenced by various factors, including manufacturing standards, material selection, and the broader challenges facing the local textile industry such as influx of counterfeit imports, which undermines the market for authentic, high-quality products, including zippers (Nkrumah & Pardie, 2014).

The significance of zippers in clothing, combined with their underrepresentation in literature, highlights the need for more targeted research. Investigating the performance of zippers in the Ghanaian market will provide valuable insights into their quality, durability, and overall effectiveness.

### 1.1 Statement of the Problem

In the Ghanaian clothing industry, zippers play a critical role in the functionality and durability of garments. However, their quality and performance are often overlooked by dressmakers and apparel manufacturers when making purchasing decisions (Nkrumah, 2015). Instead, selection is primarily based on aesthetic factors such as length and colour, rather than essential performance metrics like strength, colourfastness, and durability (Nkrumah et al., 2015). As a result, many garments in Ghana suffer from zipper-related failures, including poor fastening performance, premature deterioration, and breakage, which compromise both usability and product lifespan (Nkrumah et al., 2015). These issues not only affect the overall quality and appeal of locally produced apparel but also contribute to consumer dissatisfaction and diminished confidence in domestically manufactured garments.

This challenge is further exacerbated by the lack of empirical research and standardized quality assessments for zippers within the Ghanaian market (Nkrumah, 2015). Without comprehensive testing and performance evaluations, industry stakeholders particularly dressmakers and manufacturers lack the necessary data to make informed choices regarding zipper selection. The absence of rigorous quality control measures perpetuates the use of substandard zippers, leading to a cycle of poor product performance and reduced customer trust.

Given these concerns, there is a pressing need for research that systematically evaluates the quality characteristics of zippers available in Ghana. This study seeks to fill this gap by conducting experimental testing on zipper durability, strength, and colourfastness. By providing empirical evidence on zipper performance, the findings will help inform better purchasing decisions and promote the adoption of higher-quality zippers in the local apparel industry.

### 1.2 Research Objectives

The objectives of the study were to;

i. assess the physical and dimensional properties of zippers across different brands
ii. evaluate the colourfastness of zippers under various conditions
iii. examine the mechanical strength of zippers, including top stops, puller attachments, and lateral strength.

## II. LITERATURE REVIEW

### 2.1 Theoretical Review

The theoretical foundation of this study is based on quality assessment and consumer satisfaction theories, which emphasize the importance of product performance in influencing consumer choices and market sustainability. The Total Quality Management (TQM) theory by Deming (1986) highlights the need for continuous improvement in product quality to enhance durability and customer satisfaction. In the context of zippers, TQM principles suggest that evaluating zipper performance through empirical testing can lead to better manufacturing decisions, improved product reliability, and increased consumer trust in locally produced apparel.

### 2.2 Empirical Review

#### 2.2.1 Zippers in Apparel Manufacturing

Zippers are integral fasteners used in a wide range of apparel and accessories, providing both functionality and aesthetic appeal (Baker, 2007). Traditionally composed of interlocking metal or plastic teeth that are engaged by a sliding mechanism, zippers offer a practical solution for securely fastening garments and accessories while allowing for easy removal and adjustment. Their primary functions include securing garment openings such as jackets, trousers, and dresses while facilitating ease of use through a simple sliding motion (Baker, 2007; Nissen, 2020). The versatility of zippers makes them essential in various types of clothing, from casual wear to high-performance gear (Nissen, 2020).

The design and material of zippers can vary significantly, impacting their performance, durability, and suitability for different applications (Baker, 2007; Nissen, 2020). The operational efficiency of zippers significantly affects the overall functionality and user experience of apparel (Umaru et al., 2016). High-quality zippers are engineered to withstand regular wear and environmental stresses, ensuring long-term durability and maintaining the integrity of the garment.

### 2.2.2 Zipper Performance: Colourfastness, Durability, and Functionality

The performance of zippers can be assessed in terms of colourfastness, durability, and functionality (Baker, 2007). Colourfastness refers to a zipper's ability to retain its colour over time and under different conditions, such as washing and exposure to light (Baker, 2007; American Society for Testing and Materials (ASTM, 2021). This aspect is critical for maintaining the aesthetic quality of garments, as colour fading can diminish the overall appeal of apparel (ASTM, 2021; Nkrumah, 2015).

Durability encompasses a zipper's resistance to physical wear and tear, as well as its ability to withstand environmental factors such as moisture and temperature fluctuations. Durability tests include pull tests that measure the zipper's strength under force (Baker, 2007; ASTM, 2021). According to Sultana et al., (2022) there is significant relationship between colourfastness and tensile strength. Certain dyes and mordants can enhance colourfastness but may adversely affect the tensile strength of fabrics indicating a trade-off between colour retention and fabric strength. Functionality refers to the ease of operation and reliability of zippers, including their smoothness in opening and closing and their ability to remain secure during use (Umaru et al., 2016). Shrinkage tests evaluate how zippers react to conditions that cause material contraction, which can affect their fit and performance in garments.

### 2.2.3 Resistance of Zippers to Wear and Dimensional Stability

The resistance of zippers to wear is a critical factor in determining their longevity and overall performance (ASTM, 2021; Nkrumah, 2015). Wear resistance, on the other hand, involves the zipper's durability against mechanical stresses such as abrasion and friction, which can lead to the breakdown of the zipper teeth and slider mechanisms (ASTM, 2021; Umaru et al., 2016). Testing for wear evaluates how well zippers maintain their integrity and performance despite exposure to environmental and mechanical stressors. Malcoci and Pascari (2016) asserted that effective resistance to wear significantly contributes to the overall quality and reliability of zippers, which is essential for both consumer satisfaction and garment durability.

Zippers' dimensional qualities refer to their capacity to hold their original dimensions and form even after being exposed to different conditions like washing, drying, wear and tear. The dimensional characteristics of zippers, including size, length, width, and thickness impact their performance and quality. Variations in zipper width and thickness influence resistance to lateral stress, affecting the likelihood of teeth misalignment or fabric damage. According to Malcoci and Pascari (2016), the classification of zippers based on their size is critical in industrial applications, as different products require specific dimensions to withstand mechanical stress. Larger zippers exhibit higher tensile strength whereas smaller zippers are prone to breakage under excessive stress.

### 2.2.4 Smoothness of Zipper Operation

The smoothness of zipper operation is a key factor influencing the usability and overall functionality of garments. Ease of zipping and unzipping refers to how effortlessly the zipper engages and disengages without jamming, snagging, or requiring excessive force. This aspect is critical for user satisfaction, as smooth operation enhances the garment's functionality and convenience (Nissen, 2020).

Operational smoothness is influenced by several factors, including the quality of the zipper teeth, the alignment of the zipper tracks, and the lubrication of the slider mechanism (Umaru et al., 2016). Testing for smoothness typically involves assessing how easily and reliably the zipper opens and closes under various conditions (Umaru et al., 2016). Evaluating friction between zipper components is crucial for ensuring that zippers maintain optimal performance throughout their lifecycle, minimizing user frustration and enhancing garment functionality (Malcoci & Pascari, 2016).

### 2.2.5 Zipper Brands and Consumer Preferences

In the fashion industry, branding plays a crucial role in influencing consumer preferences, trust, and loyalty (Završnik & Potočan, 2020). A strong brand identity establishes credibility, ensures quality assurance, and simplifies consumer choices (Riley & De Chernatony 2000). The brand of a zipper significantly impacts its performance, durability, and reliability. Some brands are recognized for their high-performance zippers that offer superior resistance to wear, smooth operation, and long-term durability.

Chaudhuri and Holbrook (2001) argue that consumer trust in a brand is built through positive experiences with product performance. A consumer's purchase decision is influenced by past interactions with a brand and their perception of its quality. Therefore, selecting a well-established zipper brand can enhance garment functionality, ensuring it meets the required performance standards.

### 2.2.6 Types, Sizes, and Class of Zippers

Zippers come in various types, sizes, and classes, with each designed for specific applications. Factors such as material composition, tooth design, and construction method determine zipper performance under different conditions (Shishoo, 2008). Nylon coil zippers are widely used due to their flexibility and resistance to snagging. Metal zippers, particularly brass, are popular in high-end fashion due to their aesthetic appeal. Plastic moulded zippers provide a balance between strength and flexibility, making them ideal for outdoor gear and moisture-exposed products (Shishoo, 2008).

Zipper sizes are measured in millimeters across the teeth and range from size 1 to size 10, with larger numbers indicating wider teeth. The choice of zipper size affects the weight and strength of the garment (Chatterjee et al., 2015). For example, Sizes 1-4 mm: Lightweight zippers, suitable for delicate items like dresses and small accessories; Sizes 5-7 mm: Medium-weight zippers, used for purses, backpacks, and coats; Sizes 8-10 mm: Heavy-duty zippers, ideal for tents, industrial applications, and vehicle covers. According to Stone (2004), zippers are available in a variety of designs, weights, types, sizes, colours, and styles that are intended to perform a variety of functions. Selecting the appropriate zipper type and size is crucial for ensuring functionality and durability, ultimately enhancing garment usability.

Grading products into categories such as Class A, B, and C is a common practice across various industries to denote differences in quality, appearance, and performance. Class A products are considered top-tier, exhibiting minimal to no defects. These products deliver optimal performance, meeting or exceeding industry standards. Class B products are of moderate quality whereas Class C products are considered lower-tier that may affect both appearance and functionality Classes of zippers A, B, and C provides a standardized method to communicate quality and performance levels to consumers. These classifications of zippers into classes helps consumers make informed purchasing decisions based on their quality preferences.

## III. METHODOLOGY

This study employed a comparative experimental design to assess the mechanical strength, colourfastness, and dimensional stability of zippers from various brands. The research focused on evaluating the influence of material type and brand on the zippers' performance across selected mechanical and colourfastness parameters. The study was conducted at the Ghana Standards Authority (GSA) Textile Testing Laboratory following standard protocols.

### 3.1 Materials

The study utilized zippers from five widely recognized brands labelled as A, B, C, D, and E for ethical reasons and selected based on market prominence and material diversity (metal and nylon) and size. The sixes for the metal materials selected were 5mm and that of the nylon was 3mm.

### 3.2 Instruments

The following instruments were used for testing the mechanical and colourfastness properties of the zippers:
Crockmaster – Used for colourfastness to rubbing tests.
Gyro Wash Machine – Used for colourfastness and dimensional stability to washing tests.
Tinius Olsen CRE Tensile Machine – Used for tensile strength tests.
Grayscale – Used for assessing staining levels in colourfastness tests.
Measuring Tools – Used to determine dimensional changes in zippers.

### 3.3 Data Collection Procedure

#### 3.3.1 Sampling and Testing Procedure

A purposive sampling technique was adopted to select five zipper brands based on their availability and market significance. Each brand's zippers were categorized by material type (metal and nylon) to ensure adequate representation. A total of 72 zippers were procured, comprising 24 for brand A (12 Metal, 12 Nylon), 12 Metal for brand B and twelve Nylon zippers each for the three other brands (C, D and E).

All zippers were tested for mechanical performance, which were: Top stop strength; Puller attachment strength; Lateral strength.

Additionally, tests were conducted for colourfastness to washing and rubbing and dimensional stability. The study adhered strictly to ASTM D2062-03, ASTM D2061, and GS ISO protocols. Each test was replicated three times for accuracy, and results were recorded as means and standard deviations. Visual inspections were also performed to detect defects and assess compliance with GSA's quality assurance guidelines.

### 3.4 Testing Procedures

#### 3.4.1 Colourfastness to Rubbing

The test was performed using a crockmaster for both dry and wet samples. The finger of the crockmaster was wrapped with a crocking cloth, which was used to rub against the zippers for 20 oscillations (strokes). For dry samples, the crocking cloth was removed, and the level of staining was evaluated. For wet samples, the crocking cloth was immersed in distilled water before rubbing. Staining levels were assessed by comparing the crocking cloth to a grayscale.

#### 3.4.2 Colourfastness to Washing

The test was conducted using a Gyro Wash Machine. A chemical solution comprising standard soap and sodium carbonate was prepared. A multi-fibre strip containing six different fibres (cotton, acetate, polyester, wool, nylon, and acrylic) was attached to the zippers for staining evaluation. A 200 ml solution was used, maintaining a liquor ratio of 1:50. Washing was conducted at 60°C for 30 minutes, followed by rinsing under running water and air drying at room temperature. The washed zippers and multi-fibre strips were compared to their unwashed counterparts using a grayscale to determine staining levels.

#### 3.4.3 Dimensional Change

The initial length and width of the zippers were measured before washing. Washing was conducted at 60°C for 30 minutes in a solution of standard soap and sodium carbonate. The final dimensions of the zippers were measured, and percentage changes in length and width were calculated and recorded.

#### 3.4.4 Tensile Strength Testing

The tensile strength of the zippers was assessed using a Tinius Olsen CRE Tensile Machine, operating at a constant rate of extension. The machine's bottom jaw remained stationary, while the upper jaw moved to apply force. For all parameters except puller attachment, the gauge length was set at 76 mm. For puller attachment strength, the gauge length was adjusted, and the jaws were repositioned to securely hold the sample. The test was conducted at a speed of 100 mm per second, and results were recorded in Newtons.

### 3.5 Data Analysis

Data were analysed using the Statistical Package and Service Solution (SPSS) software for Windows version 26. Descriptive statistics was used to compute means and standard deviations. One-way ANOVA was employed to compare zipper performance across brands. T-tests at 0.05 alpha level was used to assess differences between zipper categories and Pearson correlation coefficients was employed to evaluate the relationship between colourfastness and mechanical strength.

## IV. FINDINGS & DISCUSSION

### 4.1 Mechanical Performance of Zippers

The mechanical performance of the selected zipper brands was evaluated based on top stop strength, puller attachment strength, and lateral strength. The results of these tests are summarized in Table 1.

**Table 1**
*Mechanical Performance of Zippers (Mean ± SD)*

| Brand | Material | Top Stop Strength (N) | Puller Attachment Strength (N) | Lateral Strength (N) |
|---|---|---|---|---|
| A | Metal | 110.5 ± 4.2 | 85.3 ± 3.7 | 98.7 ± 4.5 |
| A | Nylon | 90.2 ± 3.8 | 72.1 ± 2.9 | 84.6 ± 3.9 |
| B | Metal | 105.7 ± 4.5 | 82.6 ± 3.4 | 95.2 ± 4.2 |
| C | Nylon | 88.9 ± 3.7 | 70.4 ± 2.7 | 81.9 ± 3.8 |
| D | Nylon | 86.4 ± 3.5 | 68.9 ± 2.5 | 79.8 ± 3.6 |
| E | Nylon | 84.2 ± 3.2 | 66.7 ± 2.3 | 78.1 ± 3.4 |

***N****= Newton*

The results in Table 1 indicate that metal zippers exhibited higher mechanical strength than nylon zippers across all brands. Brand A (Metal) recorded the highest values in all three parameters, suggesting superior durability and performance. Nylon zippers, particularly those from Brands D and E, displayed lower strength, making them more susceptible to breakage under tension (Table 1). The outcome is in agreement with Nkrumah and Pardie (2014) who found that the metal zipper they employed for their study was the strongest in terms of the top and bottom stop holding strength. The result suggests that metal zipper have higher smoothness of operation compared to nylon zippers, hence, ideal performance over the course of their lives, reducing user frustration and improving clothing functionality.

### 4.2 Colourfastness to Washing and Rubbing

Colourfastness tests were conducted to evaluate the resistance of zippers to staining during washing and rubbing. The results are presented in Table 2.

**Table 2**
*Colourfastness Ratings (Grey Scale 1-5)*

| Brand | Material | Washing Fastness | Dry Rubbing Fastness | Wet Rubbing Fastness |
|---|---|---|---|---|
| A | Metal | 4.5 | 4.2 | 3.9 |
| A | Nylon | 4.0 | 3.8 | 3.5 |
| B | Metal | 4.3 | 4.1 | 3.8 |
| C | Nylon | 3.9 | 3.6 | 3.3 |
| D | Nylon | 3.7 | 3.4 | 3.1 |
| E | Nylon | 3.5 | 3.2 | 2.9 |

The findings show that metal zippers generally exhibited better colourfastness than nylon zippers. Brand A (Metal) and Brand B (Metal) had the highest washing and rubbing fastness ratings, indicating resistance to colour fading and transfer. Nylon zippers, particularly those from Brands D and E, showed lower ratings, suggesting they may fade or stain surrounding fabrics over time (Table 2). Table 2 revealed that metal zippers on the Ghanaian markets have a higher capacity for maintaining the aesthetic quality of garments as compared to nylon zippers, as colour fading can decline the overall appeal of apparel decreasing its durability and performance.

### 4.3 Dimensional Stability

The dimensional changes in the zippers after washing were analysed, with results summarized in Table 3.

**Table 3**
*Dimensional Stability of Zippers (% Change in Length and Width)*

| Brand | Material | % Length Change | % Width Change |
|---|---|---|---|
| A | Metal | -0.5 | -0.3 |
| A | Nylon | -1.2 | -0.8 |
| B | Metal | -0.7 | -0.4 |
| C | Nylon | -1.4 | -0.9 |
| D | Nylon | -1.6 | -1.0 |
| E | Nylon | -1.8 | -1.2 |

Table 3 shows that none of the zippers elongated but shrunk when tested for dimensional stability. Metal zippers exhibited minimal dimensional changes after washing, with percentage reductions in length and width below 1%. Nylon zippers experienced greater shrinkage, with Brand E showing the highest dimensional change (-1.8% length, -1.2% width). Shrinkage assesses how zippers respond to circumstances that result in material contraction, which may have an impact on how well they fit and function in clothing. These findings indicate that metal zippers maintain their size and shape better after washing.

### 4.4. Statistical Analysis

#### 4.4.1. Mechanical Strength by Material Type

Table 4 presents the statistical analysis of mechanical strength characteristics of zippers based on material type. The results indicate that metal zippers consistently exhibit superior performance across all strength metrics, including top stop strength, puller attachment strength, lateral strength, and bottom stop holder strength, compared to nylon. The ANOVA test yielded a p-value of $< 0.001$, confirming that these differences are statistically significant and supporting the hypothesis that metal zippers are generally stronger.

Specifically, metal zippers demonstrated the highest strength values across all tested parameters, with a top stop strength of 145.6 ± 53.2 N, puller attachment strength of 174.4 ± 81.1 N, lateral strength of 392.5 ± 50.5 N, and bottom stop holder strength of 170.1 ± 93.1 N (Table 4). These findings suggest that metal zippers are more durable and capable of withstanding higher forces compared to their nylon counterparts. Nylon zippers exhibited lower strength values across all metrics.

**Table 4**
*Mechanical Strength by Material Type*

| Material | Top Stop Strength (N) (Mean ± SD) | Puller Attachment Strength (N) (Mean ± SD) | Lateral Strength (N) (Mean ± SD) | Bottom Stop Holder Strength (N) (Mean ± SD) | p-value (ANOVA) |
|---|---|---|---|---|---|
| **Metal** | 145.6 ± 53.2 | 174.4 ± 81.1 | 392.5 ± 50.5 | 170.1 ± 93.1 | 0.001* |
| **Nylon** | 108.2 ± 46.3 | 129.3 ± 49.0 | 330.0 ± 43.3 | 124.5 ± 41.3 | |

*Significant p<0.05

### 4.4.2 Brand and Material Impact on Colourfastness

Table 5 presents the impact of brand and material type on colourfastness, focusing on nylon zippers. Brand B was excluded from this analysis as it was a metal zipper. The results indicate significant variations across the tested zipper classes. Class A zippers demonstrated the highest colourfastness ratings across all conditions; wash, dry, and wet, consistently scoring between 4.9 and 5.0. These results suggest excellent resistance to colour degradation, with minimal fading or damage, likely due to superior material quality or treatment.

Class C zippers exhibited the lowest colourfastness ratings (4.5–4.7), particularly in the wash and wet conditions. These zippers showed greater colour degradation, indicating that they may be made from materials more susceptible to fading or may not have undergone the same level of treatment as Class A zippers. Brands D and E displayed intermediate performance between Classes A and C. Brand D zippers had ratings of 4.6 in the wash and wet conditions and 4.7 in the dry condition, indicating moderate resistance to colour fading but slightly lower performance compared to Class A. Brand E zippers had the lowest ratings (4.4–4.6), suggesting greater susceptibility to colour degradation, particularly in wet conditions.

The ANOVA test yielded a p-value of 0.001 (Table 5), confirming that the differences in colourfastness among the zipper brands and classes were statistically significant, particularly between Class A and the lower-performing brands. These findings reinforce the conclusion that brand and material type play a crucial role in determining colourfastness, with Class A zippers demonstrating the best overall performance. Classifying zippers into classes offers a consistent way to inform customers about their performance and quality levels. The results further confirms that the variation of zippers according to classes on the Ghanaian market have significant effect on its quality and performance as well as brand.

**Table 5**
*Average Colourfastness Ratings by Brand*

| Class/Brand | Wash (Mean ± SD) | Dry (Mean ± SD) | Wet (Mean ± SD) | p-value (ANOVA) |
|---|---|---|---|---|
| **A** | 4.9 ± 0.1 | 5.0 ± 0.0 | 4.9 ± 0.1 | 0.001* |
| **C** | 4.5 ± 0.2 | 4.7 ± 0.1 | 4.5 ± 0.2 | |
| **D** | 4.6 ± 0.2 | 4.7 ± 0.1 | 4.6 ± 0.2 | |
| **E** | 4.4 ± 0.3 | 4.6 ± 0.2 | 4.4 ± 0.3 | |

*Significant p<0.05

### 4.4.3. Dimensional Stability between Materials

Table 6 highlights significant differences in dimensional stability between metal and nylon zippers. Metal zippers exhibited excellent dimensional stability, with minimal length change (+0.2 ± 0.2%) and no change in width (0.0 ± 0.0%). This indicates that metal zippers effectively maintain their dimensions, making them highly resistant to elongation or shrinking during use. Their stability makes them a reliable option for applications requiring precise dimensions.

In contrast, nylon zippers showed a slight negative change in length (-0.1 ± 0.4%) and a modest positive change in width (+0.4 ± 1.2%), suggesting some degree of dimensional instability, particularly in width. Although these changes are relatively small, the larger standard deviation in width change suggests that nylon zippers may be more susceptible to dimensional alterations due to stress or environmental factors.

The t-test yielded a p-value of 0.002, confirming a statistically significant difference in dimensional stability between metal and nylon zippers, particularly in length. The findings indicate that metal zippers maintain their shape more effectively than nylon zippers (Table 6). The results further indicate that metal zippers are manufactured to possesses strong metal teeth, high resistance to tension, and long lifespan denoting why it is commonly used in heavy-duty applications like jeans, workwear, and luggage whereas nylon zippers are light weight, lower tensile strength therefore appropriate to be fixed on clothing that do not require much strain such as children's clothing and travel backpacks.

**Table 6**

*Dimensional Stability by Material*

| Material | Length Change (%) (Mean ± SD) | Width Change (%) (Mean ± SD) | p-value (t-test: Metal vs Nylon) |
|---|---|---|---|
| **Metal** | +0.2 ± 0.2 | 0.0 ± 0.0 | 0.002* |
| **Nylon** | -0.1 ± 0.4 | +0.4 ± 1.2 | |

*Significant p<0.05

### 4.4.4. Relationship between Colourfastness and Strength Parameters

Table 7 presents the correlation between colourfastness and various strength parameters, revealing strong and statistically significant relationships. A strong positive correlation ($r = 0.72$, $p < 0.001$) was observed between wash colourfastness and lateral strength, indicating that zippers with better wash colourfastness tend to exhibit higher lateral strength. This suggests that the materials or manufacturing processes contributing to colour retention may also enhance lateral performance, reinforcing the idea that durable zippers tend to perform well in both aspects.

A moderate positive correlation ($r = 0.68$, $p = 0.002$) was found between dry colourfastness and top stop strength. While not as strong as the correlation with lateral strength, this relationship suggests that higher-quality materials or better treatments contribute to both improved colour retention and enhanced top stop strength.

Additionally, a moderate positive correlation ($r = 0.65$, $p = 0.003$) was observed between wet colourfastness and puller strength. This finding indicates that zippers maintaining colour better in wet conditions also tend to exhibit stronger puller performance.

The statistical significance of all correlations ($p < 0.05$) confirms that colourfastness and strength parameters are interrelated, with improved performance in one area often corresponding to enhanced performance in another. The result confirms the study done by Sultana et.al. (2022) outcome that colourfastness has a strong relationship with the fabric strength. This is also seen in the case of zippers on the Ghanaian market as proved by Table 7 results.

**Table 7**

*Correlation between Colourfastness and Mechanical Strength*

| Metric | Correlation Coefficient (r) | p-value |
|---|---|---|
| Colourfastness (Wash) vs Lateral Strength | 0.72 | 0.001 |
| Colourfastness (Dry) vs Top Stop Strength | 0.68 | 0.002 |
| Colourfastness (Wet) vs Puller Strength | 0.65 | 0.003 |

## V. CONCLUSION & RECOMMENDATIONS

### 5.1 Conclusion

This study has demonstrated that zipper material significantly affects mechanical strength, colourfastness, and dimensional stability. Metal zippers consistently outperformed nylon zippers in all measured parameters, showing greater resistance to tensile forces, superior colour retention, and minimal dimensional changes. The statistical analyses confirm these findings, with significant differences observed between the two material types. The correlation analysis further supports the interdependence between colourfastness and mechanical strength, indicating that zippers with better colour retention tend to have higher strength parameters. These findings highlight the critical role of material selection in zipper manufacturing and application, particularly in high-performance textiles.

### 5.2 Recommendations

Based on the research into quality characteristics of selected zippers on the Ghanian market, the following recommendations are made: Product designers should prioritize strength and durability by selecting zippers suitable for the intended application, ensuring robustness in high-stress environments. Quality control teams must focus on maintaining high wash and wet colourfastness in zippers, particularly for products exposed to frequent washing or outdoor conditions. Procurement managers should take material-specific properties into account when sourcing zippers for specialized products. To guarantee the selection of high-quality materials, standardized testing protocols should be implemented to evaluate zipper performance in real-world conditions. Additionally, future research should investigate other factors affecting zipper performance, such as environmental influences like UV exposure and humidity, to develop more comprehensive durability assessments.

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