SEBHA UNIVERSITY CONFERENCE PROCEEDINGS, VOL.5 NO. 4 2026
DOI: 10.51984/KHSB6547

وقائع مؤتمرات جامعة سبها
Sebha University Conference Proceedings
Confrence Proceeeding homepage: http://www.sebhau.edu.ly/journal/CAS

Utilization of Libyan Grass Fibers in Styrene–Butadiene Rubber Composites: Correlation Between Filler Content and Mechanical Properties

Anour Shebani*[1,2], Hussein Etmimi[1,2], Tarik Yerro[3], Osama Ahtewish[3]

[1] Libyan Polymer Research Center, Tripoli, Libya
[2] Research and Consultancy Center, Sirte University
[3] Mechanical Department, Higher Institute of Science and Technology, Nalut, Libya

Keywords:
Correlation analysis
Libyan grasses
Mechanical properties
Natural fiber
Styrene-butadiene rubber

A B S T R A C T

In this study, local Libyan non-woody grasses—Retama raetam (known as R'tem), Stipa tenacissima (known as Halfa) or Stipagrostis pungens (known as Esbat)—were used as a reinforcement filler in styrene-butadiene rubber (SBR) composites. Motivated by previous investigations done by our group, this study aims to compare the reinforcing behavior of these three cost-effective and locally available grasses. A correlation analysis was carried out to establish the relationship between filler type and its loading with mechanical properties of the resultant composites. Composites were prepared using a twin-screw extruder with filler loadings of 10, 20, 30, and 40 wt.% relative to polymer and its mechanical properties, namely: stress at break, elongation at break, impact strength, and micro-hardness were evaluated. The correlation analysis was performed using Pearson's method to determine the coefficient of determination (R^2). Results showed that the correlation between the composite's performance and the fiber content is strongly dependent on fiber type. In general, composites made with Halfa or Esbat showed a strong relationship with all measured properties except that with the stress at break. Whereas composites made with R′tem exhibited a very strong relationship with all properties except that with the impact strength. Contrary, Halfa- or Esbat-reinforced composites showed a very weak relationship between the fiber content and the stress at break (R^2 = 0.0238 and 0.0629, respectively). However, R'tem-filled composites showed a linear decrease in stress at break with increasing fiber content, demonstrating a strong correlation (R^2 = 0.9947). similarly, elongation at break decreased consistently with increasing filler loading for all composites irrespective to the fiber type, where all composites showed $R^2 > 0.80$. Here, R'tem-filled composites displayed the strongest relationship between the elongation at break and the fiber content. Similarly, composites showed a strong linear relationship between the impact strength and fiber loading with $R^2 > 0.80$, except for that made with R'tem, which showed a weak correlation ((R2 = 0.4217)). Micro-hardness increased linearly with filler content for all composites, exhibiting very strong relationship (and positive) with $R^2 > 0.93$.

استخدام ألياف من أعشاب محلية كمواد مالئة لمطاط الستيرين-بوتادين: العلاقة بين محتوى الألياف والخصائص الميكانيكية

أنور الشيباني*[1و2] و حسين التميمي[1و2] و طارق يرو[3] و أسامة احتيوش[3]

[1] المركز الليبي لبحوث اللدائن- طرابلس -ليبيا
[2] مكتب البحوث والاستشارات- جامعة سرت – سرت -ليبيا
[3] المعهد العالي للعلوم الهندسية- نالوت ليبيا

الكلمات المفتاحية:
تحليل الإرتباط
أعشاب محلية
خصائص ميكانيكية
ألياف طبيعية
مطاط الستايرين-بيوتاديين

الملخص

في هذه الدراسة، استُخدمت أعشاب ليبية محلية غير خشبية—وهي الرتم (Retama raetam)، و الحلفاء (Stipa tenacissima ، و السبط (Stipagrostis pungens)) —كمواد مالئة مُعزِّزة في مركبات مطاط الستايرين-بوتادين (SBR). انطلاقاً من أبحاث سابقة أجريت من قبل فريقنا، تهدف هذه الدراسة إلى مقارنة السلوك التعزيزي لهذه الأنواع الثلاثة من الأعشاب المتوفرة محلياً وذات التكلفة المنخفضة. أُجري تحليل ارتباط لتحديد العلاقة بين نوع المادة المالئة ونسبتها مع الخصائص الميكانيكية للمركبات الناتجة. تم تحضير المركبات باستخدام جهاز بثق ثنائي اللولب (twin-screw extruder) بنسب تحميل للمادة المالئة بلغت 10% و20% و30% و40% وزنياً بنسبة للبوليمر كما تم تقييم الخصائص الميكانيكية التالية:

*Corresponding author: Anour Shebani
E-mail addresses: anour@prc.ly, (H. Etmimi) hmetmimi@gmail.com, (T. Yerro) tarikyerro@yahoo.com,
(O. Ahtewish) osamaahteewish@gmail.com

Article History : Received 30 May 2026 - Received in revised form 30 September 2026 - Accepted 11 November 2026

الإجهاد عند الكسر، الاستطالة عند الكسر، مقاومة الصدمات، والصلادة الدقيقة (micro-hardness). أُجري تحليل الارتباط باستخدام طريقة "بيرسون" (Pearson) لإيجاد معامل التحديد (R^2). أظهرت النتائج أن الارتباط بين أداء المركبات البوليميرية ومحتوى الألياف يعتمد بشكل كبير على نوع الألياف. بشكل عام، أظهرت المركبات المصنوعة من "الحلفاء" أو "السبط" علاقة قوية مع جميع الخواص المقاسة باستثناء الإجهاد عند الكسر، في حين أظهرت المركبات المصنوعة من "الرتم" علاقة قوية جداً مع جميع الخواص باستثناء مقاومة الصدمات. وعلى النقيض من ذلك، أظهرت المركبات المُعزَّزة بـ"الحلفاء" أو "السبط" علاقة ضعيفة جداً بين محتوى الألياف والإجهاد عند الكسر (حيث كانت قيم R^2 0.0238 و0.0629 على التوالي). ومع ذلك، أظهرت المركبات المحتوية على "الرتم" انخفاضاً خطياً في الإجهاد عند الكسر مع زيادة محتوى الألياف، مما يشير إلى ارتباط قوي (R^2 = 0.9947). وبالمثل، انخفضت الاستطالة عند الكسر بشكل مطرد مع زيادة نسبة تحميل المادة المالئة في جميع المركبات بغض النظر عن نوع الألياف، حيث سجلت جميعها قيمة R^2 أكبر من 0.80. هنا، أظهرت المركبات المحتوية على "الرتم" أقوى علاقة بين الاستطالة عند الكسر ومحتوى الألياف. كذلك، أظهرت المركبات علاقة خطية قوية بين مقاومة الصدمات ونسبة تحميل الألياف بقيمة R^2 أكبر من 0.80، باستثناء المركبات المصنوعة من "الرتم" التي أظهرت ارتباطاً ضعيفاً (R^2 = 0.4217). ازدادت الصلادة الدقيقة خطياً مع زيادة محتوى المادة المالئة في جميع المواد المركبة، مُظهرةً علاقة قوية جداً (وطردية) مع قيمة R^2 تفوق 0.93.

1. Introduction

Natural fibers from plants are increasingly used as reinforcement fillers in polymer composites because of their low density, renewability, biodegradability, and relatively good mechanical performance [1-2]. Compared to synthetic fibers, plant fibers represent an environmental, cost-effective and friendly option, especially in regions where agricultural and natural vegetation residues are abundant [3-4]. Plant fibers are broadly classified into woody fibers (derived from trees and shrubs) and non-woody fibers (derived from grasses, leaves, stalks, husks, and other annual plants). These two categories differ in their structural and chemical characteristics, which in turn influence their reinforcing behavior in polymer composites. Both categories of fiber-reinforced polymers are extensively utilized across a wide range of sectors, including the automotive, aerospace, military, marine, packaging, and construction industries [1].

Non-wood fibers are primarily derived from fast-growing plants. Over the past few decades, these fibers have attracted significant attention, particularly for composite material applications, due to their low cost, low density, high specific strength, favorable mechanical properties, nonabrasive nature, eco-friendliness, and biodegradability. Non-wood fibers can be classified based on their origin as (1) agricultural-based or agro-fibers, (2) plant biomass, or (3) grass [5]. Grass fiber is one of the important plant fibers that can be used to reinforce polymeric materials. Grass fibers are lignocellulosic in nature which consist of layers of lignin (outermost layer), hemicellulose (inner layer), cellulose (innermost layer) [6]. Non-woody materials such as grasses typically contain lower lignin levels [7] and higher ash and silica contents [8] compared to woody materials. The final properties and performance of plant fiber composites are influenced by multiple factors, including fiber type, fiber characteristics (composition, aspect ratio, morphology), surface treatment, fiber content, fiber dispersion, fiber–matrix bonding, polymer matrix type, processing conditions, and processing type and conditions. Among these, fiber content remains one of the most directly measured parameters, and is often the starting point for evaluating the reinforcing efficiency of plant fibers.

Libya is particularly rich in non-woody grass fibers, such as Stipagrostis pungens (locally known as Halfa), Retama raetam (locally known as R'tem), and Artemisia herba-alba (locally known as Esbat), which thrive in its arid and semi-arid environments. These grasses are members of the Poaceae group [9]. They are found in hot, arid regions all over Libya. These grasses vary in fiber content, chemical composition, and morphology, all of which directly affect their reinforcing potential. Recent studies [9-12] done by our group have clearly demonstrated that local grass fibers can be incorporated into styrene-butadiene rubber (SBR) composites, where fiber content significantly impacts performance. For example, tensile stress at break was maximized at a 20-30 wt.% grass fiber content, while elongation at break decreased with increasing grass loading [10-11]. These studies showed that mechanical properties such as stress at break, elongation at break, impact strength, and hardness are especially sensitive to fiber loading and its interaction with the above-mentioned factors or parameters. Therefore, this study focuses on systematically investigating the correlation between the fiber content of non-woody plant fibers (i.e., Libyan grasses) and the mechanical properties of polymer composites namely stress at break, elongation at break, impact strength, and hardness. By analyzing these properties, the research aims to determine optimal filler levels for balancing strength, toughness, and hardness, while highlighting the potential use of local Libyan grasses as sustainable fillers, which can be used as an alternative to woody plant fibers in the development of polymer composites.

2. Experimental

2.1 Materials

Styrene-butadiene rubber (SBR) from Parc Scientific (UK) was used as a matrix. Grass fibers including Retama raetam (known as R'tem), Stipa tenacissima (known as Halfa), and Stipagrostis pungens (known as Esbat) were utilized as fillers. They were gathered from the dry area close to the Libyan city of Nalut, which is located in the Tripolitania region at the western end of the Nafusa Mountains coastal range. They were washed with distilled-deionized water and allowed to dry at 40 °C for 48 hours. They were then grinded and sieved to obtain particles of 212 µm in size. Fig1 shows images representing the three fillers used in the present study.

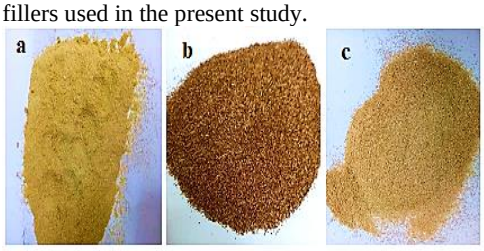


Fig. 1: Images of the grass fiber particles used in this study from a) R'tem, b) Esbat, and c) Halfa.

2.2 Methods

2.2.1 Preparation of composites

The filler particles were dried in an oven at 60°C for ~4 h, after which they were individually mixed with SBR in different proportions (10, 20, 30, and 40 wt.% relative to polymer). The mixing was achieved using a twin screw extruder (Brabender, Germany) at 180 °C and rotation speed of 70 r.p.m. with an L/D ratio of 48. The composition of all prepared composites and their codes are illustrated in Table 1. The preparation steps together with the main characterization methods are summarized in Fig. 2.

Table 1: Composition and codes of all composites prepared in this study.

Composite code	Polymer content, (wt.%)	R' tem content, (wt.%)	Halfa content, (wt.%)	Esbat content, (wt.%)
SBR	100	0.0	0.0	0.0
SBRR1	90	10.0	0.0	0.0
SBRR2	80	20.0	0.0	0.0
SBRR3	70	30.0	0.0	0.0
SBRR4	60	40.0	0.0	0.0
SBRH1	90	0.0	10.0	0.0
SBRH2	80	0.0	20.0	0.0
SBRH3	70	0.0	30.0	0.0
SBRH4	60	0.0	40.0	0.0
SBRS1	90	0.0	0.0	10.0
SBRS2	80	0.0	0.0	20.0
SBRS3	70	0.0	0.0	30.0
SBRS4	60	0.0	0.0	40.0

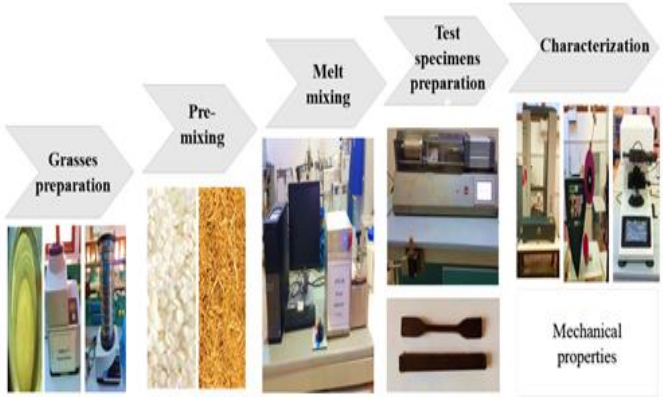


Fig. 2: Graphical summary indicating the preparation methods together with the main characterizations.

2.3 Characterization

2.3.1 Tensile strength test

Stress and elongation at break of pure SBR and its composites were determined using tensile testing machine (Cometeck QC-506M1, Taiwan) with a testing speed of 100 mm/min at room temperature. Four specimens with dimensions of (73 mm, 4 mm, and 2 mm) for each sample were examined and the average was recorded.

2.3.2 Impact strength test

The Charpy impact test was conducted utilizing a CEAST Resil Impact tester at room temperature with an impact energy of 15 J. The impact test specimens of pure SBR and all composites were prepared and notched in accordance with ASTM D256-10. For each sample, a minimum of five specimens were tested and an average was taken.

2.3.3 Micro-hardness test

The micro-hardness of pure SBR and its composites were obtained using the Vickers micro-hardness tester (MVT-1000A, China) at room temperature. The specimens were measured at a dwell time of 10 s and a load of 100 gf. The hardness value was calculated by averaging at least ten randomly selected indentations from each specimen.

2.4 Correlation analysis

Correlation analysis is normally used to analyze the relationship between two or more quantitative variables. The correlation between the mechanical properties and filler content in the polymer composites was determined using Microsoft Excel to evaluate the strength and direction of their linear relationship. A linear regression analysis was performed to establish the best-fit linear model relating the mechanical properties to filler content. The coefficient of determination (R^2) was used to assess how well the regression model explained the observed variation in the experimental data. When these two variables are correlated, changes in one is associated with changes in the other, either positively or negatively.

3. Results and discussion

3.1 Mechanical properties

The mechanical properties of pure SBR and its composites are presented in Table 2. In general, these composites exhibited mechanical properties, which depended on the type and amount of the filler used. When R'tem was used, the composite showed lower stress at break value than that of pure SBR, irrespective of the filler content. However, when Halfa and Esbat were used, higher stress at break value than that of pure SBR were obtained, which depended on the filler content. The highest stress at break value of 35.1and 33.0 N/mm^2 were obtained when 20 wt.% Halfa or Esbat was used, respectively. The mechanical properties of these composites were published and discussed in more details in a number of articles carried out by our group [10-11].

On the other hand, the elongation at break significantly decreased when the one of these grasses were added as a filler to SBR. The elongation at break deceased even more, as the amount of the filler increased. Contrary, the addition of these grasses improved the impact strength of the composite compared to pure SBR, which varied depending on the type and amount of grass added. Most composites made with R'tem, Halfa or Esbat exhibited higher impact strength than that of pure SBR. The impact strength also depended on the amount of grass used as the filler. When 30 wt.% Halfa or Esbat were used, higher impact strength than that of pure SBR and other composites was obtained. However, when R'tem was used the highest impact strength was obtained for composites made with 40 wt.% filler. The addition of R'tem, Halfa or Esbat also increased the micro-hardness of the composites. All composites made with R'tem, Halfa or Esbat showed higher micro-hardness than that of pure SBR. This also depended on the type of filler used, which increased as its amount increased. Generally speaking, the strengthening of composites can be attributed to the particle-polymer interactions that take place at the molecular level. The presence of the grass particles constrains the polymer chain deformation, which result in composites with improved mechanical properties.

Table 2: Mechanical properties of pure SBR and its composites.

Composite code	Stress at break, N/mm2	Elongation at break, %	Impact strength, KJ/m^2	Micro-hardness, HV
SBR	29.2	25.6	3.5	7.2
SBRR1	27.5	17.5	3.9	7.5
SBRR2	25.2	11.5	3.7	8.5
SBRR3	22.5	8.7	3.7	9.4
SBRR4	20.7	5.0	4.0	10.2
SBRH1	27.5	12.2	3.5	7.4
SBRH2	35.1	7.0	4.3	8.4
SBRH3	30.7	5.7	4.9	8.8
SBRH4	29.0	3.5	4.8	9.9
SBRS1	23.8	11.8	3.3	7.3
SBRS2	33.0	6.7	5.2	7.9
SBRS3	30.7	4.7	5.8	8.5
SBRS4	28.4	3.4	5.5	9.5

Here, it is crucial to emphasis that two primary findings need to be mentioned. The first finding concerns the difference between the effect of Halfa, Esbat and R'tem as the filler on the mechanical properties of the composites. Halfa and Esbat had a similar effect, where composites made with 20 wt% filler had overall stronger material than that of pure SBR. On the other hand, when only 10 wt% of R'tem was added to SBR, the mechanical properties of the R'tem/SBR composite were generally higher. Furthermore, when their content increased, Halfa and Esbat failed to provide a visible trend or behavior on stress during breaks. In a different manner, when R'tem was used, there was a distinct trend of stress at break, which decreased as the R'tem content increased.

3.2 Correlation study

The coefficient of determination is used as a statistical measure of the strength of the relationship between two or more variables. Simply, it shows the strength of the relationship between these variables. Our findings indicate that Halfa tends to reinforce SBR more effectively than R'tem and Esbat. This could be due to the different chemical structure of these grasses. In fact, cellular fibril structure, chemical composition, and structural arrangement all have profound effects on the properties of natural fiber. Each of them affects the percentage of cellulose in the fibers [13-14]. Similar to our investigation, several studies [15-16] demonstrated that superior mechanical properties were found in composites made of natural fibers with a high cellulose content. Given the foregoing results, it is great significance to investigate the relationship between mechanical properties and the content of grass fillers in order to understand their relationship and degree of interdependence. Additional information regarding the effectiveness of these grasses as reinforcement fillers for polymers might be provided by knowing the degree of correlation between the filler content and the mechanical properties of the prepared composites.

3.2.1 Filler content vs. Stress at break

The correlation analysis between the filler content and stress at break for all prepared composites is illustrated in Fig. 3. From this Figure, it's clear that when Halfa or Esbat was used there was an extremely weak correlation between filler content and stress at break of the composites (see Fig. 3 a and b). It can be seen that these composites showed very low R^2 values of 0.0238 and 0.0629 when Halfa or Esbat was used, respectively. This indicates that there is a negligible correlation or relationship between filler content and stress at break when Halfa or Esbat is used. This may be explained by the fact that, in polymer composites, tensile strength is affected by several factors and not only on filler content [17]. It is known that stress at break may depend more on fiber-matrix adhesion, fiber dispersion, fiber orientation, matrix type, void content, and processing conditions rather than just filler content [14, 18]. Other studies [11] claimed that the tensile strengths of polymer composites reinforced with natural fiber typically increase with its content until they reach an optimal or maximum value, beyond which they begin to decline. This behavior can be also attributed to the filler agglomeration and poor stress transfer. Similar findings were observed in our study when Halfa or Esbat was used as the filler. As seen in Fig.3 a and b, the threshold value of Halfa or Esbat seems to be 20 wt.% relative to polymer, after which the stress at break starts to decrease. This was discussed in more details in the section 3.1 (see also Table 2).

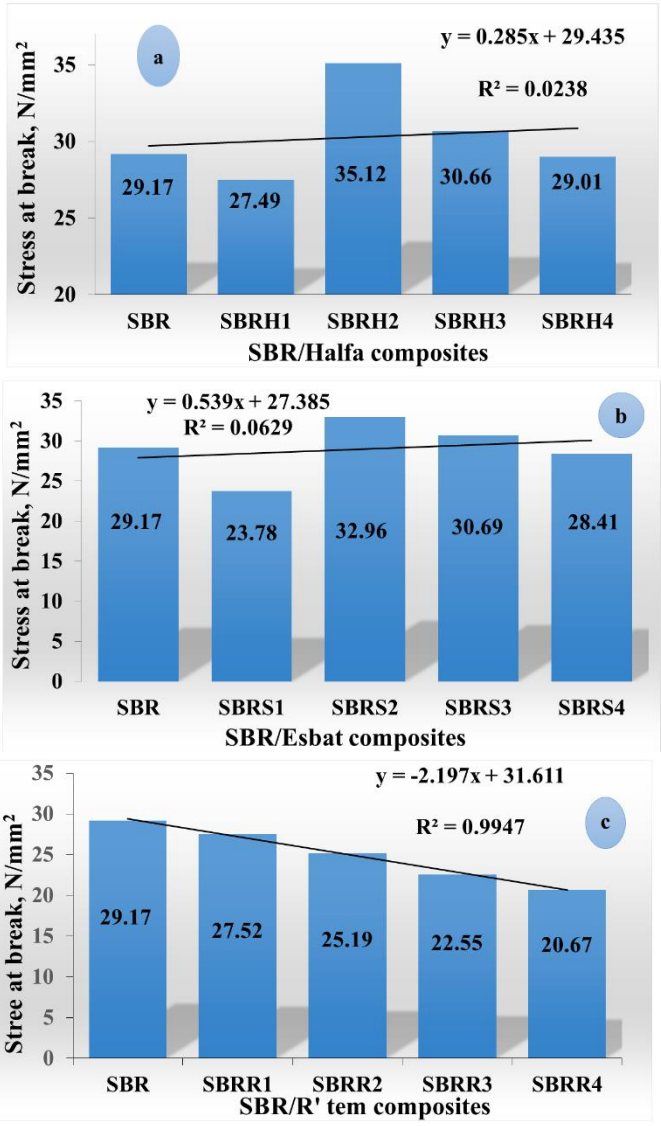


Fig. 3: The correlation between filler content and stress at break of composites made with a) Halfa, b) Esbat and c) R'tem.

In contrast, when R'tem was used there was a high correlation between stress at break and the filler content in the composite. Fig. 3 c shows that there is a strong (and negative) relationship between R'tem content and stress at break of the composite. This is clearly indicated by the high R^2 value of 0.9947. This high R^2 value suggests that the decrease in stress upon break with increasing filler content is a linear rather than random. This illustrates once again that the manner in which R'tem's effect as a filler material differs noticeably from that of Halfa or Esabt.

3.2.2 Filler content vs. Elongation at break

Fig. 4 shows the correlation analysis between filler content and elongation at break of all composites prepared.

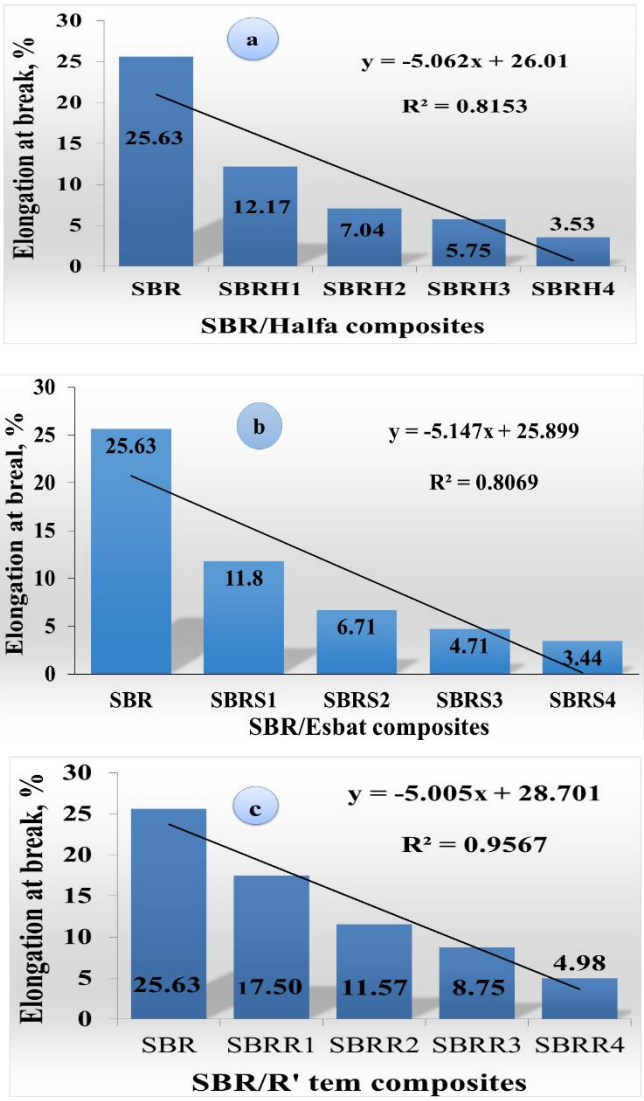


Fig. 4. The correlation between filler content and elongation at break of composites made with: a) Halfa, b) Esbat and c) R' tem.

As shown in this Figure, the correlation analysis revealed a strong and negative relationship between elongation at break and filler content in all composite. This is clearly reflected by the high R^2 value of 0.8151, 0.8069 and 0.9567 for composites made with Halfa, Esbat or R'tem, respectively. These values would indicate that the elongation behavior was significantly influenced by the filler content. However, the effect of R' tem as a reinforcing filler on elongation properties appears to differ from that of other grasses. Relatively close R^2 values of 0.8153 and 0.8069 in composites made with the Halfa or Esbat is observed, respectively. On the other hand, composite made with R'tem displayed a strong linear relationship with higher R^2 value of 0.9567. These results clearly demonstrate that the type of grass used plays an important role in governing the deformation ability of the SBR matrix with R'tem having the most distinct effect.

In line with numerous previous investigations [19-21] on natural fiber reinforcement composites, our results demonstrated that elongation at break decreased as grass content increased. The natural rigidity of these grass fibers, as opposed to the flexible SBR matrix, is the cause of the decrease in elongation. As filler loading increases, the matrix mobility is restricted, reducing its capacity to undergo deformations before fracture. Similarly, our results confirm that the incorporation of these grasses into SBR composites restricted polymer chain elongation at break. Furthermore, the correlation analysis shown in Fig 4 indicates that elongation at break is highly dependent on grass type and content in all studied composites, with R'tem showing the most pronounced

effect. This suggests that R'tem may be a more suitable reinforcing filler than Halfa and Esbat when tailoring elongation-related properties in SBR-based composites is needed.

3.2.3 Filler content vs. Impact strength

Fig. 5 shows the correlation analysis between the filler content and the impact strength of the composites. This figure also shows that impact strength changes as the amount of filler is increased. For composites containing Halfa, a high R^2 value of 0.8932 was observed, indicating a strong (and positive) relationship between filler content and impact strength. Similarly, composites containing Esbat exhibited a relatively high R^2 value of 0.8465, suggesting a strong (also positive) relationship between filler content and impact strength. In both cases, increasing filler content linearly influenced the polymer response to impact positively. Therefore, a stronger correlation observed in composites made with Halfa and Esbat suggest that the incorporation of these fibers consistently affected the energy absorption capacity of the matrix. Even in terms of resistance to impact strength, R'tem used as a filler behaved differently than Halfa and Esbat. The composites made with R'tem only displayed a weak-to-moderate correlation (R^2 = 0.4217), suggesting that the relationship between fiber content and impact strength in this composite is not linear.

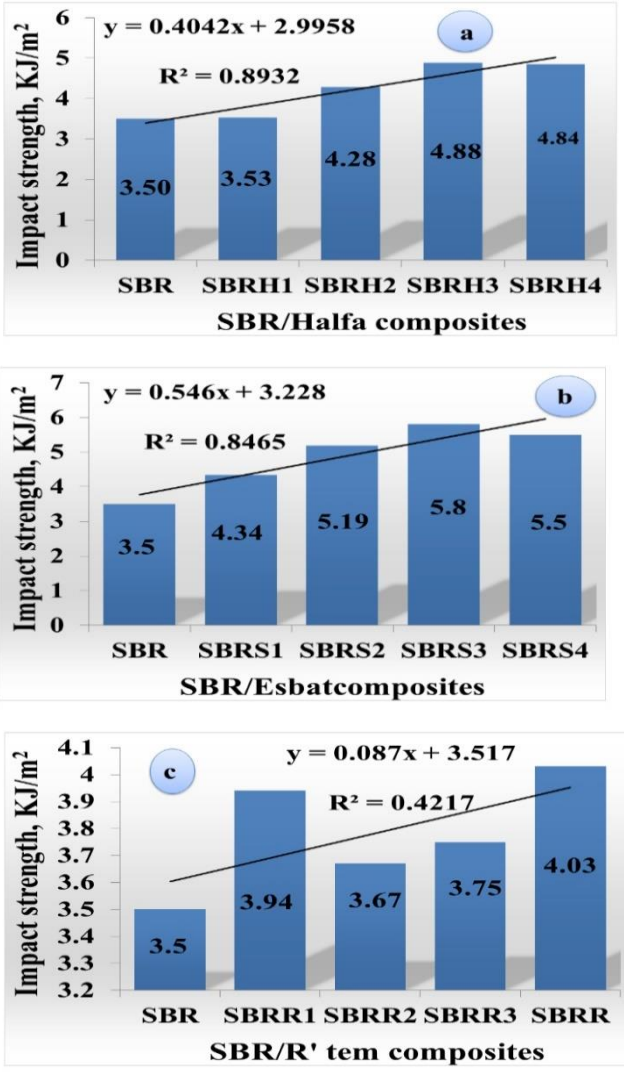


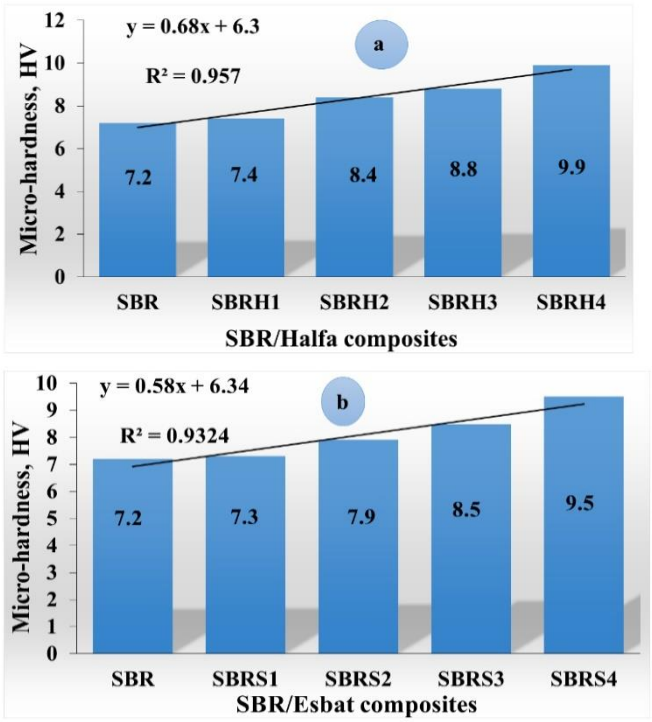
Fig. 5: The correlation between filler content and impact strength of composites made with: a) Halfa, b) Esbat and c) R' tem.

According to Abdu Mohammed and Solomon [22] the impact strength of natural fiber reinforced polymer composites is affected by fiber content, fiber length, fiber treatment, and other factors. Manjeet et al. [23] stated that a number of variables, including fiber type, weight percentage, fiber shape, surface treatments, stacking, hybridization, and fiber orientation influence the impact strength of polymer composites reinforced with natural fibers. Several investigations have shown that impact resistance can be increased by utilizing natural fiber either by using it alone or in combination with other fillers [23-24]. For example, Gupta et al. [25] found that the impact strength increases linearly with increasing fiber loading from 0 wt.% to 20 wt.% and then decreased at 30 wt.%. They also showed the any further increase in fiber loading, resulted in an increase in the impact strength. This is similar to our findings, where the impact strength of the Halfa and Esbat composites increased as the grass content increased up to 30 wt.%, after which it decreased noticeably. These results emphasize that fiber type plays a vital role in affecting the impact resistance of SBR composites. R'tem fibers were less successful in steadily controlling impact strength than Halfa and Esbat (composites made with R'tem had a low R2 value of 0.4217). This may suggest that Halfa and Esbat as a filler could be more suitable choices for tailoring SBR composites for applications requiring specific impact resistance.

3.2.4 Filler content vs. Micro-hardness

As seen in Fig. 6, a strong correlation between the micro-hardness and the amount of grass for all three types is observed. Composites made with Halfa, Esbat and R'tem all had high R^2 values of 0.9570, 0.9324 and 0.9831, respectively. These values indicate that the micro-hardness of the composites increased in a consistent manner as the amount of filler increased. The strongest correlation (R^2 = 0.9831) in composites containing R'tem indicates that R'tem's effect is still different from that of other grasses in reinforcing SBR. As mentioned above, this difference could be as a result of changes in the shape, chemical composition, or dispersion of fibers within the matrix [15].

Strong correlation of all SBR-based composites indicates that adding these grasses was greatly enhanced the SBR stiffness and rigidity. According to Alshammari et al. [26] adding filler mainly enhances the hardness, stiffness, and rigidity of polymer composites. This is due to the fact that fibers or fillers are often tougher than the base matrix material [27]. This pattern of behavior could be explained by the added grasses' restriction of the mobility of the polymer chain, which increases the composites' resistance to indentation by acting as stiff fillers [28]. Other studies [21-22] claimed that the increase in hardness of the composite may be due to stronger interface bonding of the fiber with polymer matrix. In brief, numerous researches [27-31] have demonstrated that the hardness properties increase as the filler content increases.



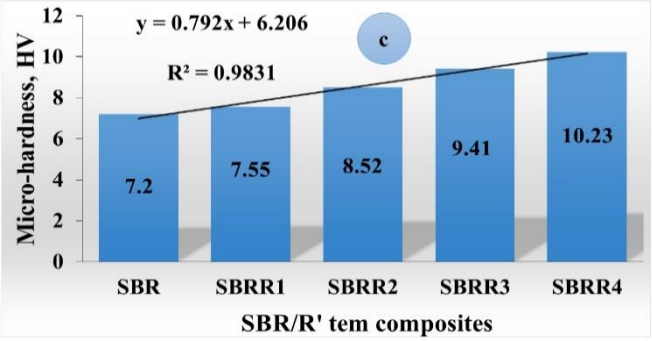


Fig. 6: The correlation between filler content and micro-hardness of composites made with: a) Halfa, b) Esbat and c) R' tem.

The overall findings of our study confirm that fiber loading is a key parameter controlling the micro-hardness of the composites, where the high R^2 values demonstrate the reliability of this relationship.

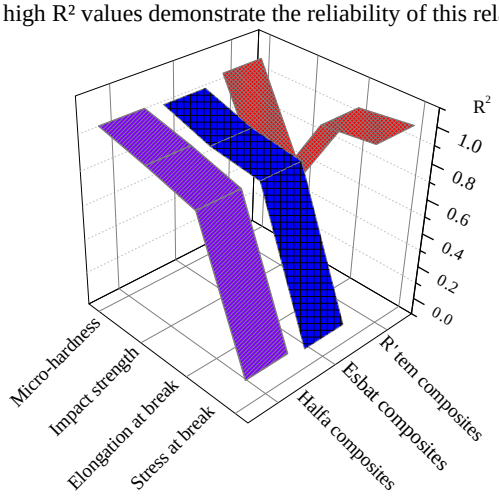


Fig. 7: R^2 values of composites containing Halfa, Esbat and R'tem in relation to the mechanical properties.

A summary of the correlation analysis which was carried out for all prepared composites is shown Fig. 7. This figure shows the R^2 values of all composites in relation to the studied mechanical properties. This analysis shows that composites containing Halfa or Esbat had a strong correlation between filler content and elongation at break, impact strength and micro-hardness. However, the same composites showed a weak correlation between filler content and stress at break. In contrast, composites containing R′tem demonstrated a very strong correlation with all measured properties except that with impact strength.

4. Conclusion

Styrene-butadiene rubber (SBR) composites reinforced with local Libyan grasses, namely Retama raetam (R'tem), Stipa tenacissima (Halfa), and Stipagrostis pungens (Esbat) were prepared. Results clearly demonstrated that both filler type and its loading significantly influence composite performance. Overall, results showed that the reinforcing behavior of R'tem differs markedly from that of Halfa and Esbat. The correlation between filler type and content with the composites' mechanical properties was investigated. Composites made with R'tem showed a very strong (but negative) relationship netween filler content and stress at break (coefficient of determination, R^2 = 0.9947). Contrary, composites filled with Halfa or Esbat-filled exhibited a very weak relationship between fiber content and stress at break was weak (both showed very low R^2 values of 0.0238 and 0.0629, respectively). This clearly indicates that tensile strength in these composites is governed more by other factors and not fiber loading. Elongation at break of all composites decreased linearly with increasing filler content. They all showed a strong relationship between the elongation at break and fiber content with R^2 = 0.8151, 0.8069 and 0.9567 for composites made with Halfa, Esbat or R'tem, respectively. On the other hand, impact strength of composites made with Halfa or Esbat increased with filler content in a more similar manner, except that made with R'tem. They exhibited strong (and positive) relationship, where (R^2 = 0.8932 and 0.8465 for Halfa- or Esbat- composites, whereas R'tem-filled composites showed a lower R^2 value of 0.4217. Micro-hardness for all composites (made with Halfa, Esbat or R'tem) increased linearly with increasing fiber content. They all displayed a very strong relationship with R^2 > 0.9570. This confirms that the stiffening of SBR matrix greatly dependent on fiber content. The findings of this study indicate that local Libyan grasses could be a promising sustainable reinforcement fillers for SBR composites especially when tailor-made properties are needed. Further studies focusing on fiber chemical composition, surface modification, and fiber–matrix interfacial interactions are recommended to optimize composite properties and broaden their practical applications.

Acknowledgements

Authors wish to thank Industrial Research Center (Tripoli- Libya) for providing the tensile test machine and the measurements.

References

1. Issam, E., Fethi, A., Mohamed, H., Furqan A., Mohamed G., Mondher N., Christian G., (2023), A Comprehensive Review of Natural Fibers and Their Composites: An Eco-friendly Alternative to Conventional Materials., Results Eng., **19**, 1–31. DOI:10.1016/j.rineng.2023.101271

2. Nezafatkhah, S., Margoto, O. H., Sassani, F., Milani, A. S., (2026), Understanding Natural and Accelerated Weathering Degradation Mechanisms of Glass and Natural Fiber Composites: A Review., J. Reinf. Plast. Compos., **45**(7–8), 1741–1763. DOI:10.1177/07316844251337240

3. Rasel, A., Kamrul, H. M., Antu, N., Jubayer R., Juhi J., Nayem H., (2025), Recent Advances in Sustainable Natural Fiber Composites: Environmental Benefits, Applications, and Future Prospects., Mater. Today Sustain., **32**, 1–26. DOI:10.1016/j.mtsust.2025.101220

4. Wagh, J. P., Malagi, R. R., Madgule, M., (2025), Investigative Studies on Natural Fiber Reinforced Composites for Automotive Bumper Beam Applications., J. Reinf. Plast. Compos., **44**(23–24), 2524–2534. DOI:10.1177/07316844241260764

5. Paridah, M. T., Juliana, A. H., Zaidon, A., Abdul Khalil H .P., (2015), Nonwood-based Composites., Curr. Forestry Rep., **1**, 221–238. DOI:10.1007/s40725-015-0023-7

6. Humar, H., Jaiswal, D. J., Hemalata, J., (2022), A State of Art Review on Grass Fiber Reinforced Polymer Composite, IOP Conf. Ser.: Mater. Sci. Eng., **1258**, 1–8. DOI:10.1088/1757-899X/1258/1/012025

7. Elita, R. W., Guangnan, C., Les, B., Catherine, H., (2018), Gasification of Non-woody Biomass: A Literature Review., Renew. Sustain. Energy Rev., **89**, 184–193. DOI:10.1016/j.rser.2018.03.023

8. Saijonkari, P. K., (2001), Non-wood Plants as Raw Material for Pulp and Paper., Agric. Food Sci., 2001. DOI:10.23986/afsci.5707

9. Shebani, A., Yerro, T., Etmimi, H., Ahtewish, O., (2025), Mechanical Properties of Styrene-Butadiene Rubber Composites Made with Mixed Local Libyan Grasses "Halfa and R'tem"., Alq. J. Med. App. Sci., **8**, 499–507. Doi.org/10.54361/ajmas.258170

10. Shebani, A., Yerro, T., Etmimi, H., Ahtewish, O., (2025), Investigating the Impact of Local Libyan Grasses: Stipa Tenacissima and Retama Raetam on Mechanical Properties of Styrene-Butadiene Rubber Composites., Polym. Bull., **81**, 14663–14677. Doi.org/10.1007/s00289-024-05400-z

11. Shebani, A., Yerro, T., Etmimi, H., Ahtewish, O., (2024), Reinforcing Styrene-Butadiene Rubber with Local Libyan Grasses; Stipa Tenacissima and Stipagrostis Pungens., Polym. Bull., **81**, 4093–4105. Doi.org/10.1007/s00289-023-04895-2

12. Shebani, A., Yerro, T., Etmimi, H., Ahtewish, O., (2024), Studying the Effect of Local Mixed Libyan Grasses, Halfa and Esbat on the Mechanical Properties of Styrene-Butadiene Rubber Composites., Sebha Univ. Conf. Proc., **3**(2), 115–120. Doi.org/10.51984/sucp.v3i2.3253

13. Khoathane, M. C., Sadiku, E. R., Agwuncha, C. S., (2015), Surface Modification of Natural Fiber Composites and Their Potential Applications, In: Surface Modification of Biopolymers, Wiley, Hoboken, 370–400. DOI:10.1002/9781119044901.ch14

14. Shesan, O., Stephen, C., Chioma, A. G., et al., (2019), Improving the Mechanical Properties of Natural Fiber Composites for Structural and Biomedical Applications., Renew. Sustain. Compos., **2019**, 1–27. DOI: 10.5772/intechopen.85252

15. Shebani, A., Van Reenen, A. J., Meincken, M., (2009), The Effect

of Wood Species on the Mechanical and Thermal Properties of Wood–LLDPE Composites., J. Compos. Mater., **43**, 1305–1318. DOI:10.1177/0021998308104548
16. Nasri, K., Loranger, É., Toubal, L., (2023), Effect of Cellulose and Lignin Content on the Mechanical Properties and Drop-Weight Impact Damage of Injection-Molded Polypropylene–Flax and –Pine Fiber Composites., J. Compos. Mater., **57**(21), 3347–3364.DOI: 10.1177/00219983231186208
17. Jesus, A. R., Chentong, G., Huiyu, S., (2025), Tensile Strength Prediction of Fiber-Reinforced Polymer Composites Through Layered Interphase and Chemical Bonding: A Semi-empirical Micromechanical Model., Eur. J. Mech. A–Solids, **111**, 105533. DOI:10.1016/j.euromechsol.2024.105533
18. Ku, H., Wang, H., Pattarachaiyakoop, N., Trada, M., (2011), A Review on the Tensile Properties of Natural Fiber Reinforced Polymer Composites., Compos. B Eng., **42**(4), 856–873. DOI:10.1016/j.compositesb.2011.01.010
19. Adeniyi, A., Abdulkareem, S., Adeoye, S. O., Joshuam O., (2022), Preparation and Properties of Wood Dust (Isoberlinia Doka) Reinforced Polystyrene Composites., Polym. Bull., **79**, 4361–4379. Doi.org/10.1007/s00289-021-03718-6
20. Onuoha, C., Onyemaobi, O. O., Anyakwo, C. N., Genevive C. O., (2017), Effect of Filler Content and Particle Size on the Mechanical Properties of Corn Cob Powder Filled Recycled Polypropylene Composites., IJSEAS, **3**(4), 145–151. www.ijseas.com
21. Mahdi, E., Dean, A., (2020), The Effect of Filler Content on the Tensile Behavior of Polypropylene/Cotton Fiber and Poly(Vinyl Chloride)/Cotton Fiber Composites., Materials (Basel), **13**(3), 1–17. DOI: 10.3390/ma13030753
22. Abdu, M. S., Solomon Alemneh, A., (2024), Review on the Impact Behavior of Natural Fiber Epoxy-Based Composites., Heliyon, **10**(20), 1–24. DOI:10.1016/j.heliyon.2024.e39116
23. Manjeet, C., Rajneesh, K., Asad, H., Ramesh, K., Upender, P., (2025), Factors Affecting Flexural and Impact Strength of Natural Fiber Reinforced Polymer Composites: A Review., Green Mater., **13**(2), 76–91. DOI:10.1680/jgrma.24.00108
24. Salman, S. D., (2022), The Influence of Kenaf Contents and Stacking Sequence on Drop-Weight Impact Properties of Hybrid Laminated Composites Reinforced Polyvinyl Butyral Composites., J. Ind. Text., **51**, 8645–8667. doi.org/10.1177/15280837209373
25. Gupta, A., Kumar, A., Patnaik, A., Sandhyarani, B.,, (2011), Effect of Different Parameters on Mechanical and Erosion Wear Behavior of Bamboo Fiber Reinforced Epoxy Composites., Int. J. Polym. Sci., **2011**, 1–10. DOI:10.1155/2011/592906
26. Alshammari, B., Alenad, A., Al-Mubaddel, F., Abdullah, G., (2022), Impact of Hybrid Fillers on the Properties of High Density Polyethylene Based Composites., Polymers, **14**, 1–15. DOI:10.3390/polym14163427
27. Abbass, O. A., Salih, A. I., Al Hurmuzy, O. M., (2020), Study of the Mechanical and Physical Properties of Biocomposite Material Based on Wheat Starch and Wheat Straw Fibers., IOP Conf. Ser.: Mater. Sci. Eng., **745**, 1–12. DOI:10.1088/1757-899X/745/1/012075
28. Faten, R. A., Mustafa, A. R., (2018), Hardness and Wear Resistance of Composite Materials Supported by Graphite and Silica Particles and Reinforced by Cuffler Fiber., Am. J. Eng. Res., **7**, 317–322.
29. Dhal, J. P., Mishra, S. C., (2013), Processing and Properties of Natural Fiber-Reinforced Polymer Composite., J. Mater., **2013**, 1–6. DOI:10.1155/2013/297213
30. Ashok, K. R. T., Mohan, N., Chavan, S. K. K., (2018), Development and Investigation of Mechanical Properties of Pongamia-Oil-Cake/UHMWPE Filled Basalt Epoxy Composites., Mater. Today Proc., **5**, 24525–24534. DOI:10.1016/j.matpr.2018.10.249
31. Bavanam, N. R., Buddha, K., Chandra, B. N. K., Dudekula, B., (2025), Development and Evaluation of a Polymer Composite Material Reinforced by Tectona Grandis Fiber, With Static Analysis., Polymers, **17**(634), 1–22. doi: 10.3390/polym17050634