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# The Effect of Spinning Parameters and Fiber Blending Ratio on the Physical Properties of Pineapple Leaf Fiber (PALF)-Cotton Yarns

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## ABSTRACT

Pineapple leaf fiber (PALF) is known as pineapple residue and has potential as a textile material. Typical yarn manufacturing adopts ring spinning technique, yet it is challenging for course fibers, including PALF. PALF has been used in clothing and paper production using textile thread. It has the highest modulus among leaf fibers, comparable to synthetic fibers such as aramid and glass, and possesses the greatest tensile strength among leaf fibers. PALF has high fineness index makes it ideal for industrial yarn and woven fabric applications. Using natural fibers offers benefits such as being environmentally friendly, cost-effective, and lightweight yet sturdy. This study evaluates the physical properties of PALF-cotton yarn at three twist speeds, two total drafts, and three PALF-cotton blending ratios. The methodology of this study involves carding, drawing, and ring spinning of the PALF-cotton fibers. The process starts with cutting and opening PALF before blending it with cotton fiber using a carding machine. The finding shows that the average diameter and fineness values range from 205 µm to 458 µm and 31.2 to 67.0 tex, respectively. The study also reported that twist speed, total draft, and blending ratio affect the diameter and fineness of the yarns. In contrast, the increment of twist speed and total draft decreases the fineness and diameter of PALF-cotton yarns. Pineapple leaf fiber (PALF) shows great potential in the apparel industry. Three regression models were presented to predict the future ring-spinning process, and pineapple waste can be repurposed into valuable products, reducing overall waste.

*Keywords:* Cotton, diameter, fineness, PALF spinning

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## INTRODUCTION

Pineapple, or Ananas comosus, belongs to the Bromeliaceae family and is one of the most popular crops planted in Malaysia (Bakar et al., 2021). Because of its enormous potential to generate income for farmers and governments, it is classified as an essential fruit (Md Ali, 2021). After Sarawak and Selangor, the state of Johor produces the most pineapples in the most significant and excellent plantation area on the peatland in Malaysia (DOA, 2021). Malaysia was placed 22nd among the top pineapple-producing countries on a worldwide scale. Pineapple waste can be used for energy generation, biofuels, and biogas. It can potentially be a source of bromelain, bioactive compounds, and cellulose nanocrystal feedstock. Pineapple waste can also be used as a bio-adsorbent to remove dyes and heavy metals. The high sugar content in different parts of the pineapple can be used as feedstocks for biofuels (Casabar et al., 2019). Nonetheless, Malaysia's economy is essential for food security, job stability, and income, particularly in small companies (Md Ali, 2021). According to the Pineapple Annual Report 2018 (MPIB, 2018), Malaysia's pineapple-based sector can help grow the socio-economy of agricultural entrepreneurs, thus helping to increase national income. By 2020, the country's demand will have increased to 3.8% due to encouraging trends in the growth rate of pineapple output over the previous ten years (Md Ali, 2021).

The rising consumer demand for pineapple has led to a substantial increase in production, resulting in the generation of a significant quantity of waste (Ali et al., 2020). During the transportation, storage, and processing of pineapples, over 80% of their components, including their crown, peels, leaves, core, and stems, are disposed of as waste (Das et al., 2022). As one of Southeast Asia's leading agricultural commodity producers, Malaysia produces 335,488 tons of pineapple, 67,098 tons of leaves, and 137,550 tons of peel wastes (Ali Hamzah et al., 2021). These wastes contain significant moisture levels, sugar, albumins, lipids, and vitamins susceptible to microbial degradation, adding to environmental issues (Rico et al., 2020). In most cases, after harvesting, pineapple residue often remains relatively unexploited and is usually disposed of or burnt in an open field. However, this method is ineffective and contributes to air pollution (Jehan et al., 2017; Omar et al., 2023). Pineapple is grown mainly for its fruit, and after harvest, the leaves remain unused, a waste of natural resources that must be explored due to the lack of fiber-specific technologies and the producers' ignorance of the various uses of the fibers, which provide additional income (Leão et al., 2015).

The demand for pineapple has increased, leading to significant waste (Ali et al., 2020) generation during transportation, storage, and processing (Das et al., 2022). Malaysia produces large amounts of pineapple waste, usually disposed of or burnt, contributing to environmental issues (Ali Hamzah et al., 2021). Pineapple residue is often unexploited, and the leaves are unused. This waste contains significant moisture levels, sugar, albumins, lipids, and vitamins, making it susceptible to microbial degradation (Rico et al., 2020).

The lack of fiber-specific technologies and producers' ignorance of the various uses of the fibers add to the problem (Leão et al., 2015).

Pineapple leaf fiber (PALF) is obtained from pineapple leaves by scraping, rotting, or decortication and used for essential purposes without additional cost (Padzil et al., 2020). PALF is white, creamy, and lustrous fiber (Dey, 2018). Various investigations show that the content of the PALF is mainly composed of cellulose, hemicellulose, lignin, wax, pectin, inorganic, and so on, with 56 to 82% of the cellulose content (Casabar et al., 2019). Compared with other natural fibers, PALF has excellent mechanical properties (Dey, 2018). The PALF has a wide range of modulus selection, varying from 34.5 to 82.51 GN/m2. Its tensile strength ranges from 413 to 1627 MN/m2, and its elongation at breaking ranges from 0.8 to 1.6%. Due to its high mechanical strength, PALF is a great material that can be used as an abrasive (BUKU PALF). Due to its high cellulose content, it has a high specific strength, rigidity, and hydrophilic characteristics. The PALF is characterized by a high average fracture strength and a low linear density, resulting in a high fiber spin capacity and a high-quality yarn (Ismoilov et al., 2019). No spinning system has been designated for the PALF (Niles et al., 2017). PALF can be turned into yarns through fiber spinning systems, such as jute spinning, semi-worsted, and flax. It can be achieved through binary or multi-blending techniques (Yusof et al., 2014). Despite the production of PALF yarns, they are still not as fine and uniform as cotton yarns in terms of properties (Ismoilov et al., 2019).

Several techniques have been developed for spinning yarn, including ring spinning, rotor spinning, and air-jet spinning. Ring spinning, which has been used since the 1770s, is the conventional method for producing yarn (Goyal & Nayak, 2019). The ring-spinning method is highly versatile and commonly used to produce yarns of excellent strength. The amount of energy used during the process depends on various factors such as fiber type, twist level (with higher twist requiring more energy), and yarn count (with finer yarns needing more energy) (Goyal & Nayak, 2019). Spinning PALF can be done manually or using machines. Initially, the long fibers were tied by hand and employed to create ropes and carpets to avoid spinning. But with the help of machines, fiber can be spun to produce better-quality textiles. However, there is currently no uniform method for spinning PALF due to its limited production and availability in the market (Jalil et al., 2021a). A technique of drafting and twisting is utilized to create yarn through spinning. The coarse sliver size is refined through the drafting system before it is spun into yarn.

PALF is generally bigger in terms of diameter than other textile fibers, namely jute fiber. Due to its big diameter, PALF produces a low percentage of quality ratios (Jalil et al., 2021b). However, this fiber could be increasingly consumed in the jute industry due to its larger diameter and lower cost than jute. Jalil et al. (2021b) reported that a high-strength fiber does not necessarily produce superior yarn unless it produces small-diameter yarn. Therefore, although the diameter of the PALF fiber is larger than jute, the spinning system and twist will affect the yarn's diameter (Jalil et al., 2021a). The diameter of the yarn decreased with increasing twist level, and compact yarns had lower diameters than regular ring yarns (Basal & Oxenham, 2006). Thus, researchers are currently focused on developing competent yarn-forming methods and controlling parameters of connected machinery to broaden textile product diversity (Jalil et al., 2021a). As a result, improving the characteristics of fibers and yarn products, spinning and weaving productivity, and marginal capital investment may motivate entrepreneurs if this technology's development message reaches people worldwide.

Due to its bigger diameter, PALF is rarely used to form woven yarn, and mixing them with finer fibers such as cotton can provide a higher fiber count per area (Jalil et al., 2021a). Previous research has produced a blended fiber from the blending ratio of cotton: PALF 90:10 and 80:20 (Jalil et al., 2021a), and other researchers produced a blended fiber with 50% PALF and 50% cotton (Ismoilov et al., 2019). Previous research has shown that blending jute with cotton fiber is a helpful way to expand the use of jute and produce more valuable products. Jute fibers have several benefits, including a shiny golden appearance, high strength, and favorable properties. Thus, blending methods can be utilized to improve the quality of jute and develop a new range of fabrics made from jute that have a rising demand in both local and international markets (Ullah et al.,2016). According to their research, fabric made of a blend of yarn and cotton has characteristics similar to those of cotton fabric. It could reduce the need for imported cotton fiber (Ullah et al., 2016). Although PALF may not be suitable for clothing, it is possible to use thicker yarns made from this fiber to create various conventional and advanced textile products (Jalil et al., 2021a).

Therefore, this study aims to evaluate the effect of twist, draft, and blending ratio on the physical properties of PALF-cotton yarn. PALF fiber has a larger diameter than jute fiber, which affects the yarn's diameter (Jalil et al., 2021b). Researchers are focused on developing competent yarn-forming methods and controlling machinery parameters to create a variety of textile products (Jalil et al., 2021a). Blending PALF with cotton can produce a higher fiber count per area. Fabric made of a blend of yarn and cotton has characteristics similar to those of cotton fabric, which could reduce the need for imported cotton fiber (Ullah et al., 2016). This study aims to evaluate the effect of twist, draft, and blending ratio on the physical properties of PALF-cotton yarn.

## MATERIALS AND METHODS

### Materials Preparation

In this study, pineapple leaf fiber (PALF) was provided by the Malaysian Pineapple Industry Board (MPIB) in Pontian, Johor. The cotton fibers were also procured from Shijiazhuang Bibante Trading Co, China. The cotton fiber properties were studied as a benchmark for the blended fiber. The average staple length of the textile cotton fibers used in this study was 34.5 mm, while the effective diameter was 16.58 µm.

## Sample Preparation

Once the pineapple fruit is harvested between 146 and 152 days from the first day of flowering, the leaves are carefully detached from the trunk. The process of extracting PALF is executed manually through a meticulous decoration technique involving scraping and preparations. PALF fibers were cut into 3 to 4 cm long staple lengths, and PALF-cotton yarns' 1 meter in length, morphology, and physical properties were evaluated.

Prior to the spinning process, the PALF was manually cut into 3 to 4 cm in length to ease the fiber blending and spinning process. There are three majors: producing yarn opening, carding, drawing, and ring spinning. At the beginning of the process, cotton fibers underwent a carding machine to ease the condition of the fibers. Then, the feeding apron with PALF-cotton fibers was put into a carding machine according to the specified ratios. This study prepared the PALF and cotton fibers in three ratios: 30% PALF + 70% cotton, 40% PALF + 60% cotton, and 50% PALF + 50% cotton. Next, PALF and cotton fibers began the blending process using the carding machine. The formation of a sliver was also carried out through the carding machine. The quality of the yarn produced heavily relies upon the formation of slivers, which involves the removal of short fibers. Later, the carded sliver produced from the carding machine was the input for the ring spinning machine. The last process of manufacturing PALF cotton involves the ring-spinning process. Figure 1 illustrates the steps involved in the preparation of yarn. In this study, three levels of twisting speed (800 tpm, 850 tpm, and 900 tpm) and two levels of drafting (8 and 10 total drafts) were adjusted in the control panel of the ring spinning machine. Figure 2 depicts the sample preparation flowchart for this study. The study consists of five stages: preparation of pineapple fiber, blending of PALF-cotton fiber, preparation of PALF-cotton sliver, production of PALF-cotton yarn, and analysis of PALF-cotton yarn.

Eighteen samples of PALF-cotton yarn with three different blending ratios, three twisting speed levels, and two total draft levels were used to produce the yarn. Table 1 presents the parameters of the research studies on the PALF-cotton ratios, the studies' designation, the number of ratios, levels of twisting speed, and the number of total drafts. Besides, the ring frame speed (rpm) was kept constant at 5600 rpm in the ring spinning machine. The Spinning Technology Laboratory, located at the Faculty of Engineering Technology in Universiti Tun Hussein Onn Malaysia, housed the carding and ring spinning machines.

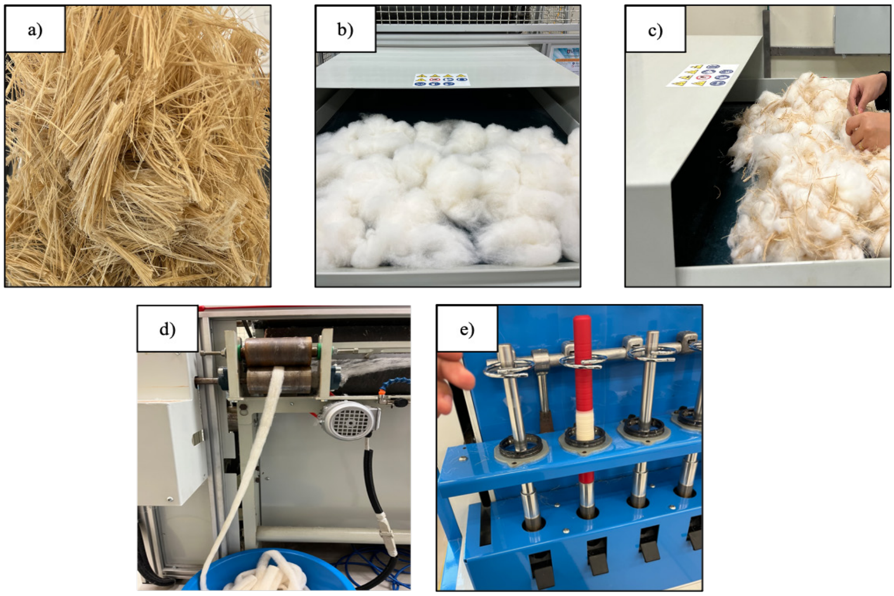



*Figure 1*. Sample preparation process of (a) PALF fiber; (b) opening cotton fiber; (c) feeding apron where PALF-cotton fiber was placed; (d) sliver development from the carding machine; (e) yarns production

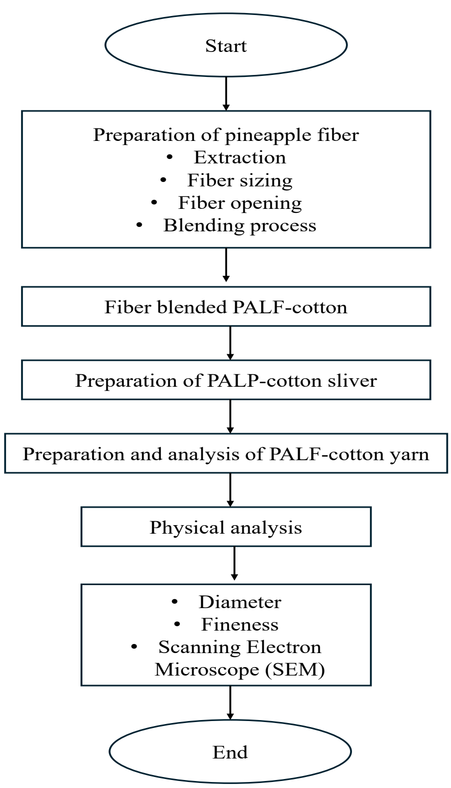



*Figure 2* Sample preparation flowchart

Table 1
*Parameters of PALF-cotton yarn*

| Designation | Ratios (%) | Twisting speed (tpm) | Total draft |
|---|---|---|---|
| 30A | 30/70 | 800 | 8 |
| 30B | | 850 | |
| 30C | | 900 | |
| 30D | 30/70 | 800 | 10 |
| 30E | | 850 | |
| 30F | | 900 | |
| 40A | 40/60 | 800 | 8 |
| 40B | | 850 | |
| 40C | | 900 | |
| 40D | 40/60 | 800 | 10 |
| 40E | | 850 | |
| 40F | | 900 | |
| 50A | 50/50 | 800 | 8 |
| 50B | | 850 | |
| 50C | | 900 | |
| 50D | 50/50 | 800 | 10 |
| 50E | | 850 | |
| 50F | | 900 | |

### Analysis of Variance (ANOVA)

An investigation was carried out to analyze the thickness and quality of PALF-cotton yarn, utilizing the general linear model (GLM) of analysis of variance (ANOVA) with the help of MINITAB 19 Software. The ANOVA identified the most prominent group that significantly impacted the outcome. If the p-value is less than 0.5, there are differences between the averages at a 0.05 significance level. Besides, the experimental data was fitted by the quadratic regression model. Equation 1 describes the relationship between the independent variables and the response variable:

$$Y_i = \beta_0 + \beta X_i + \varepsilon_i \qquad (1)$$

Where $Y_i$ is the *c* value of the dependent or response variable, $\beta_0$ and $\beta_1$ are the coefficients of the regression line (also known as the slope ($\beta_1$)) and intercept ($\beta_0$), $X_i$ is the *i*-th independent or predictor variable, and $\varepsilon_i$ is the prediction error, or "noise" or "residual." The regression model was carried out for the future yarn qualities based on the spinning parameters or yarn properties.

### Yarn Diameter

Advanced Microscopy (Model Olympus U-MSSP4), located at the Material Science Laboratory, Faculty of Engineering Technology, UTHM, was used to measure the yarn diameter. To measure the diameter, the lens's magnification was set to 5x. A total of 90 yarn were measured, and 10 mm long yarn samples were made. The average diameter was determined by measuring it five times along the length of PALF-cotton yarn. Under a high-magnification microscope, the diameter of representative sampling fibers can be measured using the standard method test procedure adopted by ASTM D2130-90 (ASTM International, 2008).

### Yarn Fineness

The measurement of yarn fineness using the standard gravimetric method, which involves cutting and weighing the yarn, was based on ASTM D 1907 (ASTM, 1989). In total, 90 yarns were measured, each cut to a length of 1 meter, and weighed five times to obtain the average yarn weight. The entire process was repeated five times to arrive at an average fineness for the yarn. The materials were precisely weighed to within 0.001 g using a calibrated balance after being divided into 10 cm pieces. The determination of yarn fineness was done using Equation 2. This mathematical formula computes the mass of the yarn per unit length in tex, where tex is the measure of yarn mass in grams per 1000 meters of length. A higher tex value indicates that the yarn is coarser, and its fineness is inversely proportional to this value (Equation 2).

$$\text{Yarn finess } \left(\frac{\text{mass}}{\text{length}}\right) \text{X } 100 \qquad (2)$$

### Scanning Electron Microscope (SEM) Analysis

The morphology and structure of PALF-cotton surfaces were observed by using Scanning Electron Microscopy device model no: JEOL JSM-6380LA MP-19500014, located at Material Science Laboratory, Faculty of Mechanical and Manufacturing (FKMP), Universiti Tun Hussein Onn Malaysia (UTHM). Platinum coating of a few thick nanometers coated the PALF-cotton yarn surfaces. The SEM analysis was carried out to identify the comparison imperfection of yarn subjected to the different spinning parameters.

## RESULTS AND DISCUSSION

### Yarn Physical Properties

Table 2 displays the ANOVA table for PALF-cotton at different spinning parameters and blending ratios subjected to diameter and fineness properties. Table 2 shows that twist speed, total draft, and blending ratio significantly affected the diameter of the yarn. Additionally, both spinning parameters and blending ratios significantly affected the fineness, with *p*-values indicated lower than 0.05.

Table2
*ANOVA results for diameter and fineness*

| Source | DF | *F*-value | *P*-value | Significant level |
|---|---|---|---|---|
| 1. Diameter | | | | |
| Twist Speed | 2 | 48.82 | 0.000 | *** |
| Draft | 1 | 42.14 | 0.000 | *** |
| Blending Ratio | 2 | 54.11 | 0.000 | *** |
| | | | | |
| 2. Fineness | | | | |
| Twist Speed | 2 | 23.21 | 0.000 | *** |
| Draft | 1 | 47.72 | 0.000 | *** |
| Blending Ratio | 2 | 35.03 | 0.000 | *** |

Note:
*** Significantly different at $p<0.001$

In this study, all three parameters, namely twisting speed $\chi 1$ and total draft $\chi 2$, were chosen as the potential influences, and Yi were dependent variables calculated by the proposed model. The quadratic regression models that have been fitted and their significance are presented in Table 3. The $\beta$-coefficient for different yarn quality parameters. The calculation of beta coefficients involves standardization of variables, which means subtracting their means and dividing by their standard deviations. This analysis is performed to arrive at the values of beta coefficients. The coefficient of determination shows the percentage of response variable variability the model explains. Examining standardized variables, after dividing them by their means and standard deviations, leads to estimations known as beta coefficients. Standardizing coefficients is necessary when variables are measured in different units to evaluate how well independent variables influence the response variable in fitted models.

Table 3
*Response fineness equations of PALF-cotton yarn on the ratio*

| Ratio (%) | Response fineness equation |
|---|---|
| 30:70 | $506.4 - 0.5100\, x_1 - 42.33\, x_2 + 0.04833\, x½$ |
| 40:60 | $1031.9 - 01.1600\, x_1 - 87.81\, x_2 + 0.10.333\, x½$ |
| 50:50 | $261.7 - 0.1283\, x_1 - 8.01\, x_2 + 0.0042\, x½$ |

Figure 3 illustrates the average diameter of the PALF-cotton yarn. The blending ratio apparently shows the most significant effect on the average diameter. Generally, the increment of the PALF ratio increased the average diameter, especially at 50% of PALF yarn. From observation, the increment of the PALF ratio initially slightly decreases the average diameter of PALF-cotton yarn with 40% of PALF presence in the yarn. However, the average diameter increases significantly when the yarn ratio increases to 50%. Moreover, the increment of twist speed and total draft decreases the average diameter of PALF-cotton yarns, especially at 40% and 50% of PALF presence.

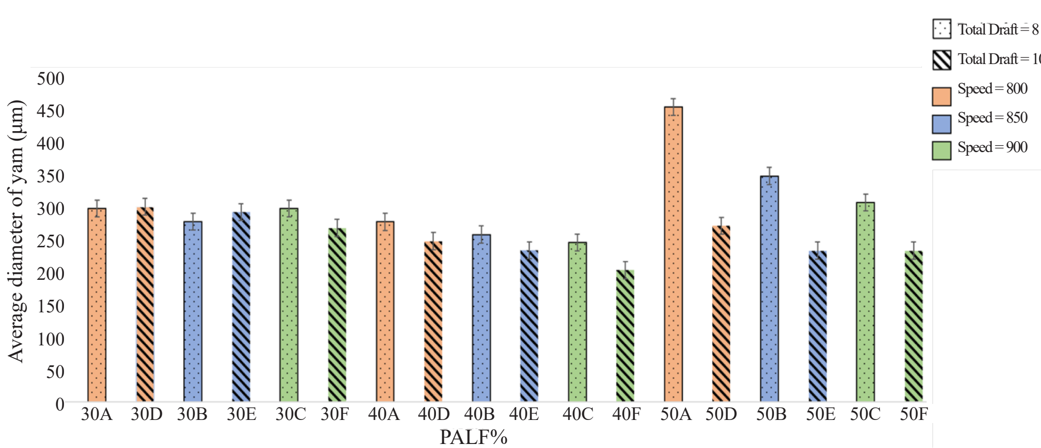



*Figure 3*. The average diameter of the PALF-cotton yarn is subjected to the different PALF blending ratios, twisting speeds, and total draft

Yarns 50A (50% PALF + 50% cotton, 800 twist speed, and 8 drafts) and 40F (40% PALF + 60% cotton, 900 twist speed, and 10 drafts) exhibit the highest and the lowest average diameter at values of 458 µm and 205 µm, respectively. Yarn 50A has the highest diameter yarn due to the high amount of PALF fibers compared to others. These findings are tallied by Jalil et al. (2021a) due to a higher diameter, which could be affected by less fine. Hence, its coarseness and brittle nature cause the yarn to become loose and not interlocked with each other yarn in the blending ratio of 50% PALF + 50% cotton. Furthermore, from the previous study, yarn produced from 100% PALF has a larger diameter relative to other textile fibers, and due to this larger diameter, PALF will produce poor quality ratios (Jalil et al., 2021a). In a nutshell, 100% PALF fiber is not recommended to be spun alone to produce a better quality of yarn (Jalil et al., 2021b). On the other hand, twisting speed, draft and blending ratio had a significant effect on the diameter response, with p-values indicating lower than 0.05.

However, yarn 40F is smaller than those with 30% of PALF. It has been predicted that different ratios of cotton fiber in the PALF-cotton yarn 40F have a lower ratio of cotton (Jalil et al., 2021a). This study also revealed that higher twist speed (900 twist speed) and total draft (10) contribute to the smaller yarn diameter to produce high-quality yarn. These findings are similar to a study by Basal and Oxenham (2006), where the high speed and high total draft contributed to greater diameter or yarn.

Figure 4 illustrates the fineness of the PALF-cotton yarn subjected to the different twist speeds, total draft, and PALF ratio. Generally, the twist speed, total draft, and blending ratio affect the fineness of the yarn. The increment of twist speed and total draft decreases the fineness of PALF-cotton yarns, and the trend was exhibited in the yarn comprising 40% and 50% PALF. In the fineness study, the increment of the PALF blending ratio affects the fineness of the yarn.

The highest fineness value is given by yarn 30A (30% PALF + 70% cotton, 800 twist speed, and 8 drafts), followed by 40A (40% PALF + 60% cotton, 800 twist speed, and 8 drafts) and 50A (50% PALF + 50% cotton, 800 twist speed, and 8 drafts), with the values of 67.0 tex, 66.7 tex, and 66.4 tex, respectively. It indicated that at 800 twist speed and 8 drafts, it was able to spin the yarn and produce at similar fineness, regardless of the blending ratio of PALF. Meanwhile, the lowest values are given by 50F (31.2 tex), followed by 40C (31.4 tex) and 50E (31.8 tex). Low fineness is one of the good qualities of yarn. As reported by Jalil, low fineness resulted in excellent-quality yarn (Jalil et al., 2021b).

Next, since the text is proportional to the fineness of the yarn, a greater tex value indicates coarser yarn, and a lower tax value indicates finer yarn (Anuwar et al., 2022). Besides that, yarn fineness decreases as the twisting speed decreases because the adjustment of spinning parameters in twisting speed will control the input into the top front roller at the ring spinning machine. Based on previous research, blending more fine cotton fibers with PALF helps to enhance spinnability (Jalil et al., 2021a).

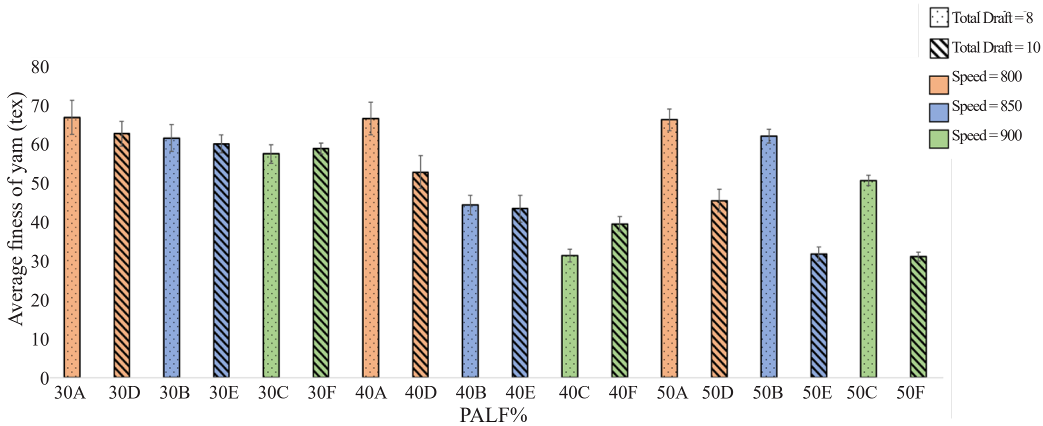



*Figure 4.* The fineness of the PALF-cotton yarn is subjected to the different PALF blending ratios, twisting speeds, and total draft

## Morphology Analysis

The SEM image analysis was taken with 70x magnification. The yarn's structure micrographs can be seen in Table 4, which compares the surface morphologies subjected to different blending ratios, twisting speeds, and total draft. The SEM aims to analyze the morphology of PALF yarn. Surface Morphology in Table 4 shows the difference in morphology by increasing and decreasing the ratio of PALF + cotton, total draft, and twisting speed. A Visual inspection in Table 4 showed that 40% PALF + 60% cotton was found with an increased twisting speed of 800, 850, and 900 tpm, and total drafts 8 and 10; hence, will reveal a uniformity increase in the PALF-cotton yarn. Next, the structure of the yarn becomes significantly looser by decreasing the twisting speed, and the twisting speed increases the tighter structure.

According to the previous researcher, increasing the twisting level and adjusting the spinning systems will be significant by reducing yarn hairiness and improving the quality of yarn spinning (Basal & Oxenham, 2006). At the same time, the 50% PALF + 50% cotton total draft 10 revealed that the yarn size is smaller than draft 8. Thus, it had a tighter yarn structure. As a result, a looser structure of 50% PALF + 50% cotton was detected at 850 and 800 twisting speeds. Thus, from the previously obtained, the physical properties of constituent fibers and the yarn structure play important roles in yarn properties (Jalil et al., 2015). This study also revealed that 30% PALF + 70% cotton yarn by decreasing the PALF ratios and increasing the cotton fiber ratio size of the yarn affected the size of PALF-cotton yarn. As reported by Tursunbayevich et al. (2021), when yarns spun in a different spinning system are twisted, the strength of the yarns increases (Tursunbayevich et al., 2021).

Table 4
*Surface morphology of PALF-cotton yarn*

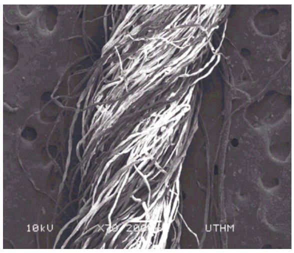
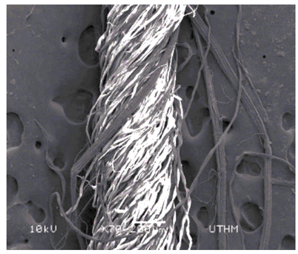
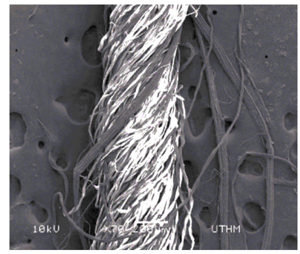
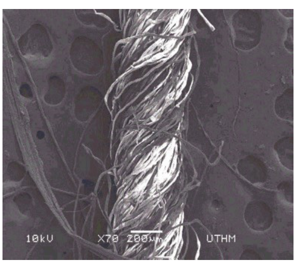
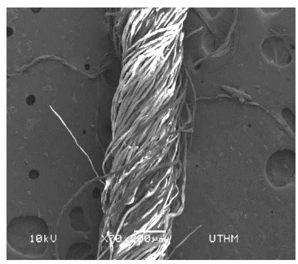
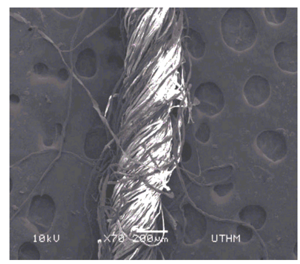
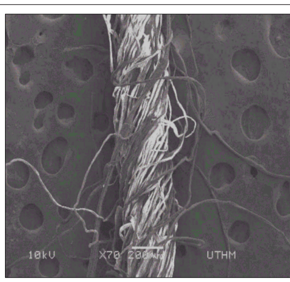
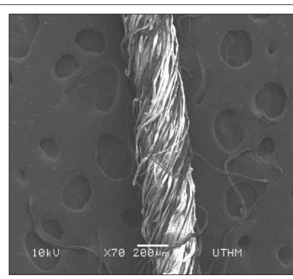
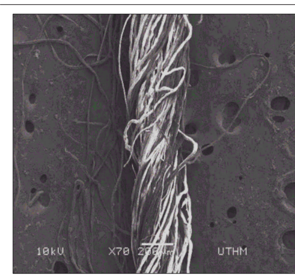
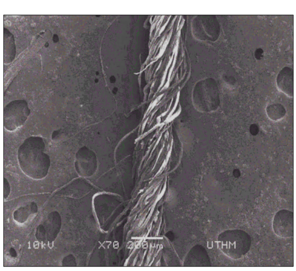
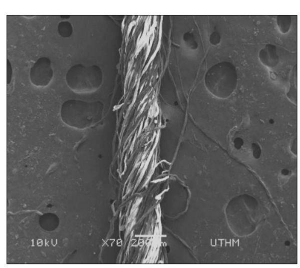
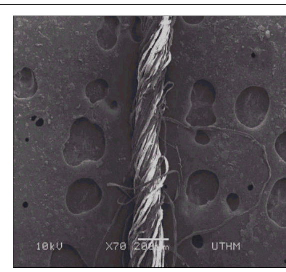
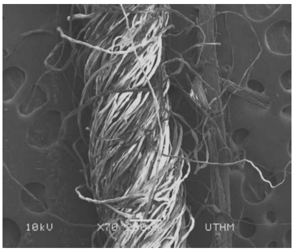
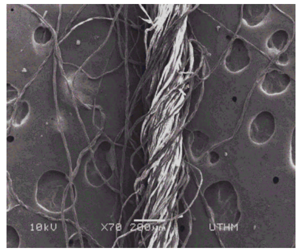
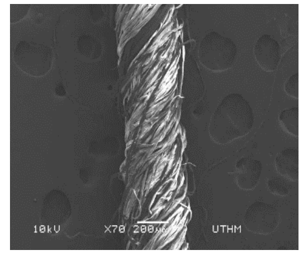
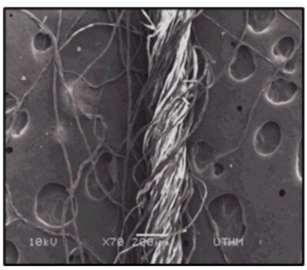
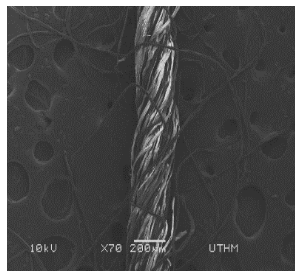
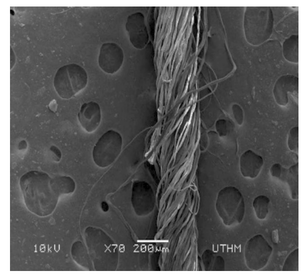
| | 800 tpm | 850 tpm | 900 tpm |
|---|---|---|---|
| | **30% PALF + 70% cotton** | | |
| 8 drafts |  |  |  |
| 10 drafts |  |  |  |
| | **40% PALF + 60% cotton** | | |
| 8 drafts |  |  |  |
| 10 drafts |  |  |  |

Table 4 *(Continue)*

| | 50% PALF + 50% cotton | | |
|---|---|---|---|
| | 800 tpm | 850 tpm | 900 tpm |
| 8 drafts |  |  |  |
| 10 drafts |  |  |  |

## CONCLUSION

In conclusion, the diameter and fineness of PALF-cotton yarns were successfully evaluated. It was discovered that the different twist speeds and draft adjusting during the ring spinning process influenced the diameter and fineness of the yarns. PALF-cotton yarn developed by blending ratio of 50% PALF + 50% cotton achieved the best structure in terms of the fineness and compact structure of the yarn. Spinning parameters of 850 twist speeds and 10 total drafts are recommended to produce PALF-cotton yarn. Further preparation on raw PALF fiber can be undertaken, especially in the treatment process, to enhance PALF fiber characteristics and achieve a better quality of yarn. Generally, PALF processing and manufacturing could produce zero waste in Malaysia with the contribution of the textile industry. The blended yarn has great potential for producing fancy clothing items. The study concluded that the findings could directly impact the PALF and cotton industry. Implementing the suggested method could yield better-quality yarns and fabrics. It would improve the usage of PALF, which is environmentally friendly and biodegradable. Through efficient modification, PALF can be a source of garment manufacturing that is helpful to the industry and community.

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