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Quality Ratio Comparison of Yarn Spun from Three different Varieties of Kenaf

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Abstract

The increasing potentials of kenaf fibres when spun into yarn has been a major influence on farmers desire for its continuous growth with the development and availability of a mini kenaf spinning and reeling machine for farmers. It became necessary to determine the quality ratio of the different available commercial varieties of kenaf yarn spun by the machine to be able to recommend the variety that is most suitable for the textile and other related industries. Three varieties of kenaf fibre (Tianung 2, Ifeken DI 400 and Cuba 108) were spun into yarn at three different spinning (90, 100 and 110 rev/min) and reeling (60, 70 and 80 rev/min) speeds in three replicates. The yarn counts were determined and the samples were taken to the laboratory for the determination of their strength characteristics and results obtained were used to derive the quality ratio of each spun yarn. Result of average values obtained showed that IFEKEN DI 400 produced yarn with the best quality ratio of 82.3% with yarn count of 659 tex (19.12 lbs/spy), highest young modulus of 821×10^3 (gf/tex) but with the least tensile strength (14.1 N), followed by the Tianung 2 with a quality ratio of 69.9%, yarn count of 810 tex (23.5 lbs/spy), young modulus of 814×10^3 (gf/tex) and tensile strength of 16.3 N while Cuba 108 has the lowest quality ratio of 58.4%, highest yarn count of 981 tex (28.5 lbs/spy), young modulus value of 726×10^3 (gf/tex) and the highest tensile strength of 16.8 N . The study recommends IFEKEN DI 400 as a better alternative for yarn production for applications in the textile and related industries to farmers and processors when spun at 90 and 80 rev/min for spinning and reeling speeds respectively.

Introduction

Kenaf is generally cultivated for either seeds or fibres production. Meanwhile, out of all the useful and harvestable components of kenaf plant (Fig. 1), the fibre as shown in Fig. 2 remains a major purpose of planting kenaf despite the relevance of the other components (Atta and Ogunniyan, 2024). Over the years, the importance of kenaf has been solely narrowed to the textile industry but it has now been found more useful for different industries like the oil and gas, automotive, structural etc. (Sen and Jagannatha, 2011). Kenaf was also found as a medicinal crop and it was discovered to be suitable for the treatment of different health challenges beyond expectations (Cheng 2001) while the fibre is useful in controlling environmental pollution and degradation in water fronts which is a major challenge in the Niger Delta Basin in Nigeria (Tegu *et al.*, 2023). The seeds have been identified with oil and protein

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content similar to those of cotton (Akil *et al*., 2011) thus extending its uses beyond the production intention. However, it is believed that expertise is required for kenaf seeds production with the use of appropriate technologies for its processing and storage.

On production of seeds, the Nigeria government established, empowered and mandated the Institute of Agricultural Research and Training, Obafemi Awolowo University, Ile-Ife for the continuous production and availability of viable kenaf seeds (Fig. 3) with required trainings to farmers, towards enhancing the production of kenaf in Nigeria. Kenaf has been found to be a good source of income for low and medium scale processors in Nigeria as it has been found useful for the production of beauty and care products when spun into yarn. Meanwhile, very few farmers and processors show interest towards the optimum utilization of kenaf despite its potential, due to unavailability of appropriate technologies for its processing (Oloruntoba *et al*., 2017; Ogunwusi, 2013), scarcity of land for production and under-utilization of the crop (Tahir *et al.*, 2011) although the global demand for kenaf keeps increasing.

It has also been discovered that kenaf have more potentials when spun into yarn with the properties of fibre being a major factor for the quality of the spun yarn (Chalachew, 2014). Another study carried out by Atta *et al.* (2021) on the properties of different varieties of kenaf fibres reported that the different varieties of kenaf available to Nigerian farmers had different strength characteristics which heightens the expectation of variations in the quality of the spun yarn by different varieties of fibre. Despite the narrowing the native of kenaf to Africa, the rate of production from this part of the world is still very low in compared to other continent (FAO, 2021; FAO, 2008). Meanwhile, the challenges facing the production of kenaf have not influenced the need for the crop due to its increasing importance. As the demand for kenaf grows, Ogunwusi (2003) recommended the empowerment and attraction of small-scale farmers into the production line to boost kenaf production globally which led to the innovation of a small scale kenaf fibre spinning and reeling machine by Atta and Owolarafe (2023).

With the development of the machine, it is important to test for the quality of different varieties of kenaf yarn produced to ascertain the variety with the best quality that is suitable and acceptable for further processing in the textile and other industries. The machine uses the principle of ring spinning to produce twined fibres of any desired length which could be later spun to produce double ply yarn (Atta and Owolarafe, 2023).

Fig. 1: Kenaf plant

Fig. 2: Kenaf Seed

Fig. 3: Kenaf Fibre

Materials and Methods

Fig. 4 shows an exploded view of the kenaf spinning and reeling machine. The developed kenaf fibre spinning and reeling machine that is found suitable for the production of single ply yarn (Fig. 5) and double ply yarn (Fig. 6) basically for small and medium scale farmers was used to spin three different varieties of kenaf fibres (Ifeken DI 400, Cuba 108 and Tianung 2) acquired from the Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan. The fibres were spun into yarn at different spinning (90,100,110 rev/min) and reeling (60, 70 and 80 rev/min) speeds as shown in the experimental design (Fig. 7). Samples were weighed and measured for the determination of the yarn count. The weighed samples were taken to the laboratory for the determination of the tensile stress, strain, young modulus and tensile strength for the determination of the quality ratio of the samples.

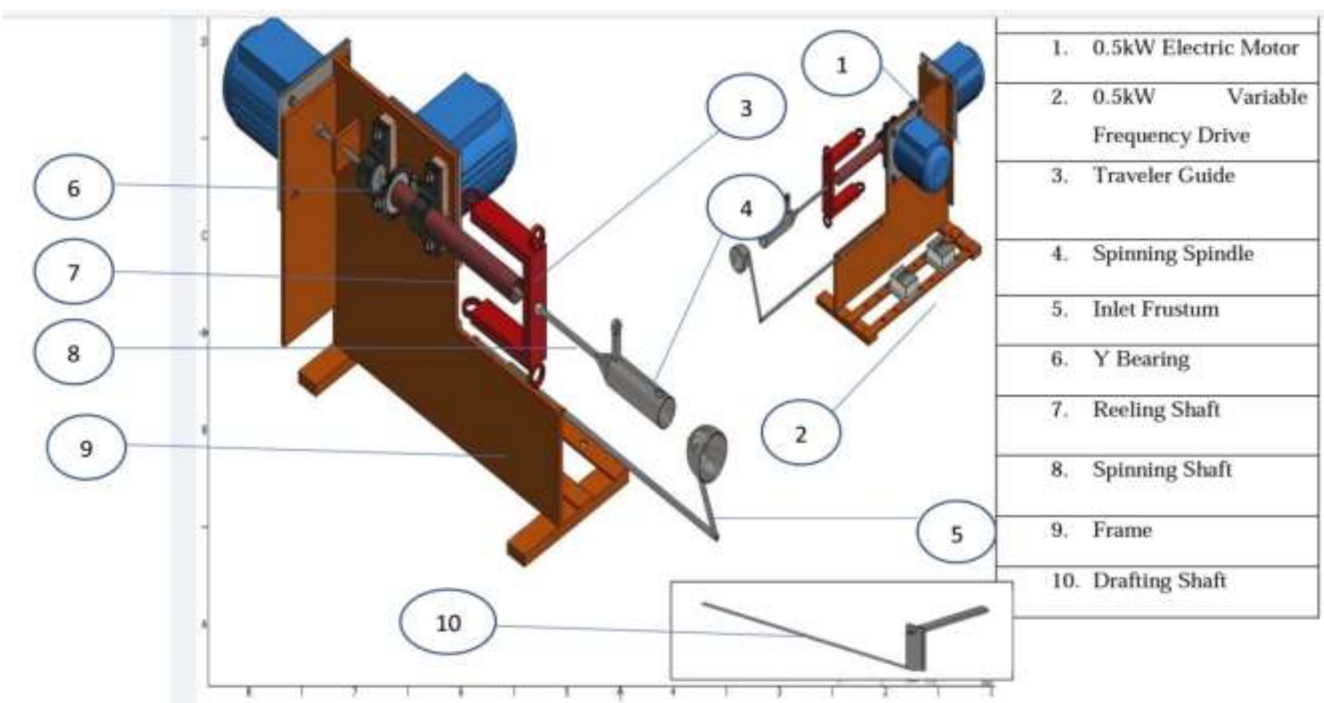

Fig. 4: An exploded view of a kenaf spinning and reeling machine

Fig. 5: Kenaf Twinning Machine (Single Ply Yarn)

Fig. 6: Kenaf Spinning Machine (Double Ply Yarn)

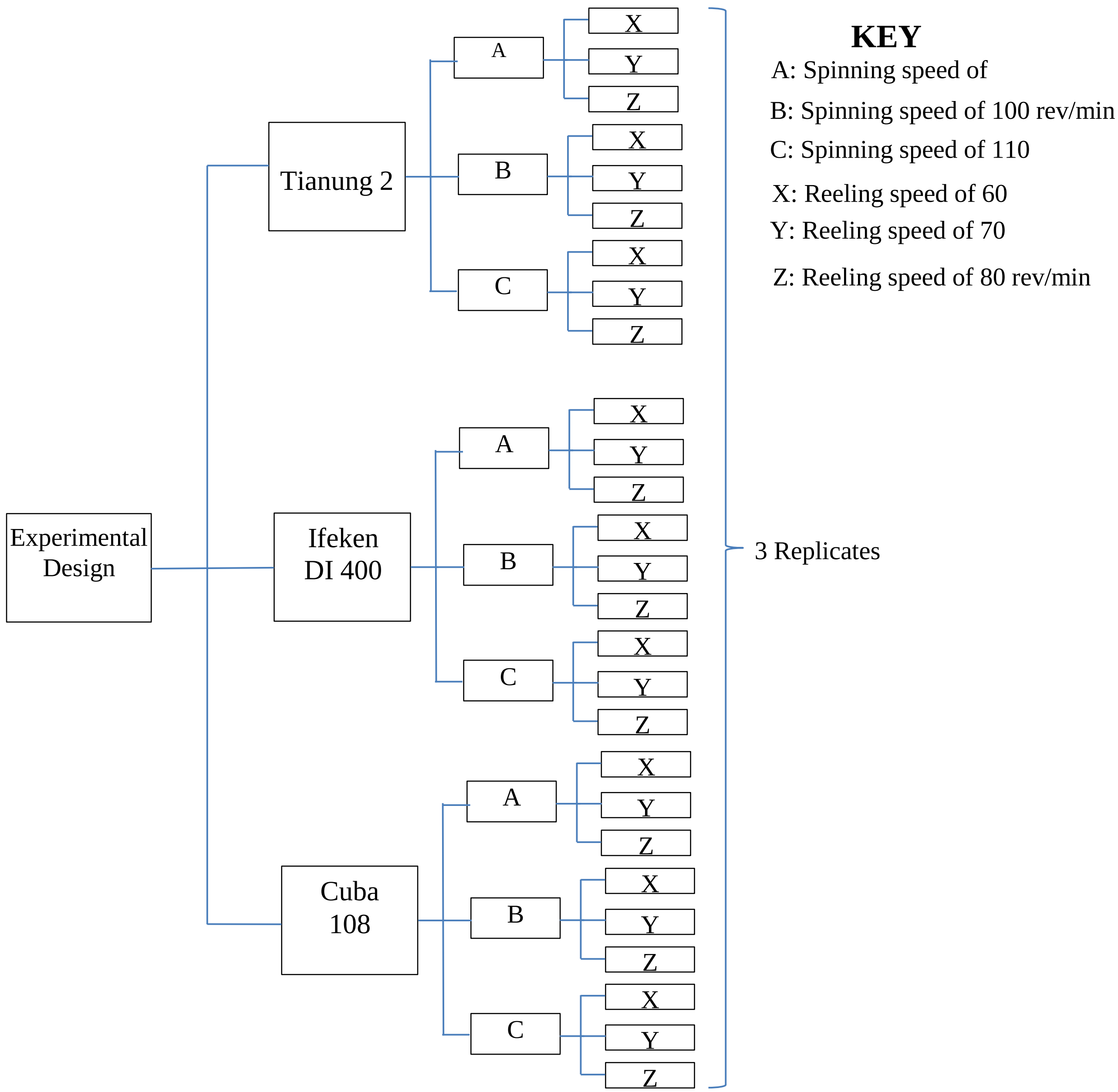

Fig 7: Experimental design for production of kenaf yarn

Mechanism of Machine Operation

Due to the nature of kenaf fibres, it is required that kenaf fibres are joined to produce a continuous length of a twine or a single ply yarn. To ensure the production of a quality spun yarn, the twining section of the machine (Fig. 5) was designed to initially join and twine kenaf fibresthat are actually staple in nature to produce a desired length and wound on a bobbin. This was achieved by feeding kenaf fibre into the machine through the inlet frustum, passed through the spindle to the traveler guide which aids the delivery of the fibre to any of the two bobbins on the reeling shaft. Additional lengths of fibre are joined as the spindle rotates while the bobbins collected the twisted length of fibre as the reeling shaft also rotates.

During the spinning operation the inlet frustum is replaced with the drafting shaft which holds the two twinned fiber bobbins (Fig. 6). Fibers from the two bobbins on the draft shaft are passed to a new bobbin on the reeling shaft following the same principle utilized in the twinning process. The spindle twists the twined fibres to form yarn as the machine is set in motion while the spun yarn is collected on the new bobbin as the reeling shaft rotates.

Yarn count (C_Y)

This is usually measured but can also be calculated. It is the measurement of a unit length of spun yarn. It is measured kg/m or in tex.

Production speed or yarn delivery speed (N_3)

The yarn delivery speed was determined as

$$N_3 = \pi \, d_r \, (N_2 - N_1)$$

where V = yarn delivery speed,
d_r = diameter of the reeling pulley (cm)
N_2 = speed of the reeling pulley (rev/min),
N_1 = speed of the twisting/spinning cone (rev/min).
Production or yarn delivery speed is measured in centimetre per minute.

Determination of count of yarn samples

To determine yarn count, it is required to measure the mass or weight of a specific or known length of yarn, usually 1 m. Yarn count is also referred to as linear density and this describes the fineness of yarn which can be expressed by different number of systems and units. To develop an efficient systems or machines for spinning fibres to yarn, it is required that such machine maintains a very good count variation, that is, should be able to maintain an average yarn count. This is usually measured but can also be calculated. It is the measurement of a unit length of spun yarn. It is measured in kg/m or in tex

Determination of quality ratio

The following formula was used to determine the quality ratio of the spun yarn according to Samad *et al.* (2002)

$$Quality\ Ratio = \frac{Tensile\ strength\ (lbs)}{Yarn\ Count\ (\frac{lbs}{spy})} \times 100$$

Results and Discussion

Fig. 8 shows the result of the production rate of kenaf yarn at different spinning and reeling speeds combination of the machine used to produce the yarn. It was discovered that the production range was between 0.94 m to 4.71 m per minute with a twist number range of 113 to 183 turns per minute (Atta *et al.,* 2023). This indicates that for any kenaf or related fibre that is fed into the machine at the varying speed combination, the production rate will be in the range. However, it is also important to understand that it is not enough to have high production rate of yarn but with good strength characteristics and quality.

Yarn count of spun kenaf fibre

It was discovered that our local variety, Ifeken DI 400 produced the finest yarn of 331 tex (9.60 lbs/spy) at the spinning and reeling speeds combination of 90 and 80 rev/min at the highest efficiency of the machine of 88.9%. Also, from Fig. 7, Ifeken DI 400 has the least mean yarn count of 659 tex (19.12 lbs/spy) while Cuba 108 has the highest yarn count of 981 tex (28.48 lbs/spy) which makes the Ifeken DI 400 the finest produced yarn while Cuba 108 is the coarsest or heaviest yarn produced. This simply indicated that the lower the yarn count, the finer the yarn produced as reported by Aisyah *et al.* (2018).

From the physical appearances of the spun yarn, it was observed that Ifeken DI 400 (which has the least or lowest mean yarn count) has very low or insignificant level of hairiness unlike Cuba 108 that produced hairy yarn. This supports the result of Kadoglu (2006) who reported that yarn with low count have less hairiness and tends to be more acceptable in the textile industry.

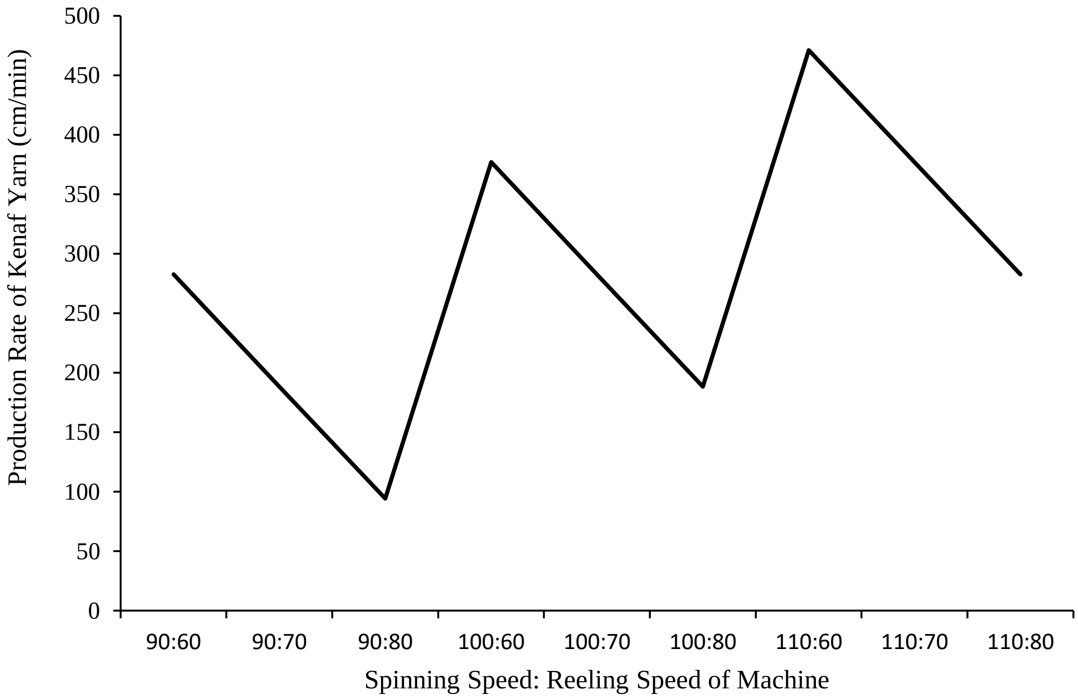

Fig. 8. Production rate of kenaf yarn

Tensile strength of Spun Yarn

It was discovered as shown in Fig. 9 that Cuba 108 with the highest mean yarn count (981 tex (28.5 lbs/spy) has the highest mean tensile strength of 16.8 N. These results are in consonance with the previous study of Shah *et al*. (2013) and Aisyah *et al*. (2018) who reported that tensile strength is directly proportional to yarn count.

Heavy yarn is formed with a greater number of individual fibres, thus requiring bigger load to break and higher number of twists for quality yarn. However, Samad *et al.* (2002) concluded that yarn strength is not directly proportional to yarn quality except the diameter of the yarn produced is small which can only be achieved with low yarn count.

Young modulus of Spun Yarn

The result of the young modulus obtained showed that Ifeken DI 400 has the highness mean value of Young modulus of 821 × 10^3 (gf/tex), which means that it has the strongest stiffness or tendency to resist deformation, followed by Tianung 2 with a close mean Young modulus value of 814 × 10^3 (gf/tex) while Cuba 108 has the least value of 726 × 10^3 (gf/tex) of the three varieties of yarn that were spun. This result is seen to be related with the yarn count of the various varieties of yarn as shown in Fig. 8. It revealed that Ifeken DI 400 with the least mean yarn count value has the highest Young modulus while the yarn with the highest yarn count (Cuba 108) has the least Young modulus value. This result is in support of the findings of Madsen *et al*. (2007) and also that of Aisyah *et al*. (2018) that yarn with lowest yarn count tends to have the highest Young modulus values. Also, it is expected that the properties of the fibre will form that of the spun yarn as reported by Chalachew (2014). The result of Ifeken DI 400 yarn with the highest value of young modulus might be influenced by the result earlier obtained and reported by Atta *et al.* (2021) that Ifeken DI 400 fibre has the highest value of young modulus when compared with other kenaf fibre varieties.

Table 1: Production rate and quality ratio of various kenaf yarn

S/N	Variety of Kenaf	Spinning Speed(rev/min)	Reeling Speed(rev/min)	Production rate (m/min)	Yarn Count tex (lbs/spy)	Tensile Strength N (lbs)	E Modulus (gf/tex)	Quality ratio (%)
1	Tianung 2	90	60	2.83	694 (20.14)	50.6(11.39)	498	56.52
2	Tianung 2		70	1.89	1400(40.64)	110.2(24.80)	701	61.01
3	Tianung 2		80	0.94	800(31.09)	105(23.63)	1491	101.74
4	Tianung 2	100	60	3.78	600(17.42)	58.3(13.11)	601	75.32
5	Tianung 2		70	2.83	581(16.88)	57.1(12.85)	648	76.13
6	Tianung 2		80	1.89	1000(29.03)	94.8(21.33)	1061	73.48
7	Tianung 2	110	60	4.71	1000(29.03)	76.6(17.24)	895	59.37
8	Tianung 2		70	3.77	646(18.75)	43.7(9.83)	733	52.45
9	Tianung 2		80	2.83	578(16.77)	54.2(12.20)	696	72.71
10	IfekenDI400	90	60	2.83	894(25.94)	67.1(15.10)	623	58.20
11	IfekenDI400		70	1.89	64418.71()	66.9(15.05)	693	80.47
12	IfekenDI400		80	0.94	331(9.60)	63.3(14.24)	708	148.31
13	IfekenDI400	100	60	3.77	744(21.60)	78.1(17.57)	1183	81.35
14	IfekenDI400		70	2.83	651(18.89)	54.3(12.22)	955	64.69
15	IfekenDI400		80	1.89	680(19.74)	55(12.38)	540	62.69
16	IfekenDI400	110	60	4.71	406(11.79)	56.2(12.65)	1017	107.23
17	IfekenDI400		70	3.77	1000(29.03)	49.6(11.16)	882	38.45
18	IfekenDI400		80	2.83	577(16.75)	74(16.65)	791	99.42
19	Cuba 108	90	60	2.83	1278(37.09)	96.2(21.65)	699	58.36
20	Cuba 108		70	1.89	617(17.91)	51(11.48)	419	64.07
21	Cuba 108		80	0.94	883(25.63)	85(19.13)	971	74.62
22	Cuba 108	100	60	3.77	1243(36.09)	96.8(21.78)	669	60.35
23	Cuba 108		70	2.83	1087(31.55)	94.1(21.17)	174	67.10
24	Cuba 108		80	1.89	959(27.84)	56.5(12.72)	1010	45.66
25	Cuba 108	110	60	4.71	1087(31.55)	94.1(21.17)	1091	67.10
26	Cuba 108		70	3.77	800(23.22)	31.54(7.10)	803	30.56
27	Cuba 108		80	2.83	875(25.40)	65.4(14.72)	699	57.94

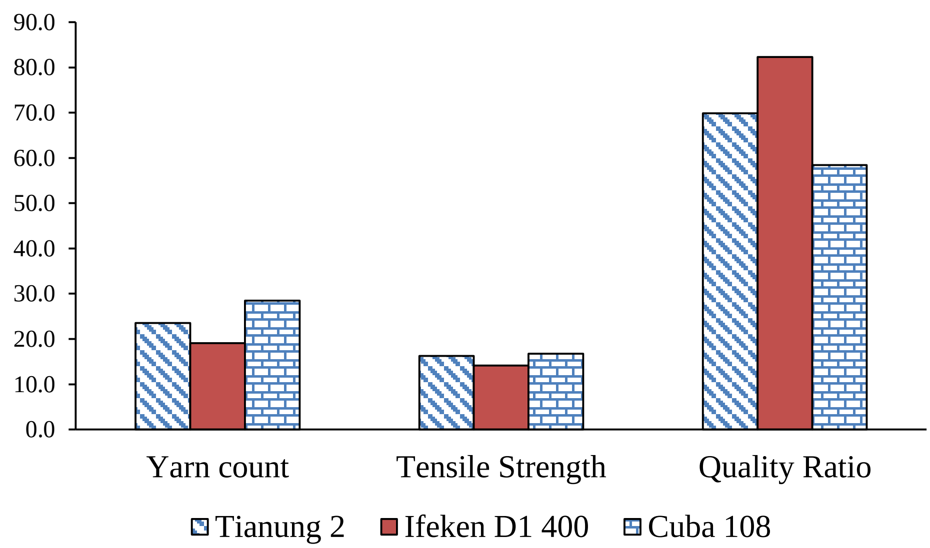

Fig. 9: Properties of different varieties of kenaf yarn

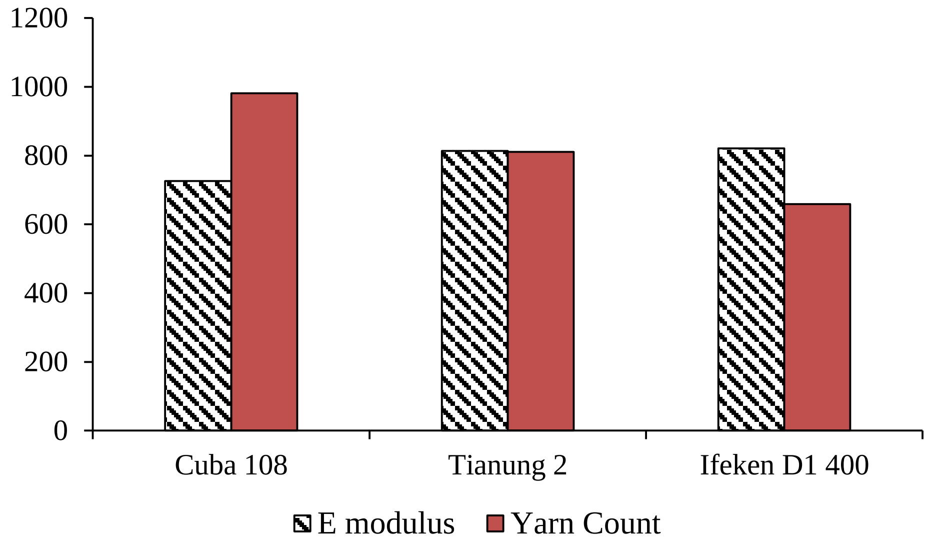

Fig. 10: E-modulus of different kenaf yarn

Quality ratio of Spun Yarn

Ifeken DI 400 has the highest quality ratio of 82.3%, followed by Tianung 2 with 70% quality ratio while Cuba 108 has the least quality ratio of 58.4%. It was discovered that yarn with the least yarn count produced the highest quality while the yarn with the highest yarn count produced the lowest quality values. This followed the trend reported by Aisyah *et al*. (2018) that yarn quality ratio increases as the yarn count decreases. The value obtained for Ifeken DI 400 was observed to have been better than the quality ratio of some previously investigated kenaf varieties such as Kenaf HC-2, (79.98%), HC-4(41.70%) and HC-95 (73.94%) as reported by Samad *et al.* (2002). Despite the quality ratio range (41.7 – 89 %) of the various spun kenaf yarn, the fibre quality ratio is still low compared to other fibres like Jute which maintains quality ratio range from 108 – 117 %. Meanwhile, despite the relatively low-quality ratio of kenaf compared to other fibre crops, kenaf are still acceptable and used for manufacturing purposes because they are cheaper and can be spun with other artificial fibre for improved quality yarn.

Analysis of variance

The result of the analysis of variance (Table 2) revealed that the effect of spinning speed, reeling speed and variety does not have a significant effect (p>0.05) on the quality ratio of the yarn but without the right combination of the spinning and reeling speeds, the quality of the yarn will be affected as shown in the significant effect (p≤0.05) of the spinning and reeling speeds interaction. Separation of means of values for spinning and reeling speeds (Table 3 and 4) revealed that the means were not significantly (p>0.05) different.

Table 2: ANOVA table

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Reeling_Speed	2	1301.32	650.66	2.08	0.1877
Spinning_Speed	2	543.97	271.98	0.87	0.4558
Varieties	2	1923.55	961.78	3.07	0.1025
Spinning_*Reeling_Sp	4	5580.73	1395.18	4.45	0.0347
Varieties*Reeling_Sp	4	3876.92	969.23	3.09	0.0815
Varieties*Spinning_S	4	1711.10	427.77	1.37	0.3272

Table 3: Separation of means of quality ratio based on reeling speed

Reeling Speed	Mean Quality Ratio
80	79.21[a]
60	77.8[a]
70	63.83[a]

Table 4: Separation of means of quality ratio based on spinning speed

Spinning Speed	Mean Quality Ratio
110	77.91[a]
90	75.52[a]
100	67.42[a]

Conclusions

This study provided a spun yarn technology for small scale kenaf farmers and processors. The result of the study reveals that Ifeken DI 400 kenaf variety produced fibres that could offer a viable replacement to foreign breeds of kenaf in terms of mechanical properties and possibly durability in production line. The developed kenaf fibre spinning and reeling machine was able to produce continuous lengths of high quality single and double ply yarn at spinning and reeling speeds combination of 90 and 80 rev/min respectively. However, Ifeken DI 400 kenaf yarn produced the best quality ratio when compared with other local and foreign varieties of yarn spun and therefore offers a viable option in quality yarn production.

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