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Research Article

Studies on fibre quality of a long staple cotton variety using high volume instrument and advanced fibre information system for fibre quality improvement

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Abstract
Fibre quality parameters of 20 plants of a long staple cotton variety Suraj were analyzed using High Volume Instrument (HVI) and Advanced Fibre Information System (AFIS) and were compared. From AFIS data, narrow range of coefficient of variability (of less than 10 %) was noticed in characters like length (by weight), upper quartile length (by weight), length (by number), 5 % length (by number), fineness (mtex), maturity ratio and fibre neps. Comparatively larger extent of variability was noticed (of more than 10 %) for short fibre content (both by weight and by number), immature fibre content, fibre neps – count/g, seed coat neps – count/g and for seed coat neps – mean size. However, the coefficient of variability for 2.5 % span length (mm), uniformity ratio (%), micronaire (µg/inch) and tenacity at 3.2 mm gauge (g/tex) was low when the fibre quality data was generated in HVI. This shows that variability estimates were narrow in the selected plants when fibre quality was analysed in HVI and exposes inherent weakness in analysing the fibre quality with HVI in breeders' perspective. Correlation coefficients between immature fibre content and short fibre content, both by number (r = 0.89) and by weight (r = 0.84) were very high indicating that by reducing short fibre content the immature fibre content can be reduced drastically. Further, the correlation between immature fibre content and tenacity at 3.2 mm gauge was negative and was high (-0.91). Plants with ideal combination of yield and fibre quality parameters were identified for further exploitation.

Key words: Cotton, Fibre quality improvement, Short fibre content, Immature fibre content, Tenacity, AFIS, HVI

Introduction

Cotton has been used from antiquity for its seed hairs in the production of yarn and fabric. Fibres vary in length from less than 12.7 mm, which cannot be spun into yarns, to over 30 mm (Smith *et al*. 2010). Cotton, the "White Gold" is cultivated in different agro-climatic conditions in India mainly for its fibre, which constitute about 62 per cent of the raw material requirement of Indian textile industry. It is important to note here that the research and technology initiatives, safe cultivation practices and their on-farm demonstrations on a large scale have resulted in increase in cotton yield. The cotton production (356 lakh bales) and the productivity (496 kg/ha) in 2012-13 bears testimony for this (Anonymous 2013).

In spite of heavy inroads of hybrids, especially Bt cotton hybrids, occupying more than 90 per cent of the total area under cotton cultivation, the extra long staple varieties capable of spinning 60^s count yarn still occupies a sizeable area in the South Zone states of Tamil Nadu, Karnataka and Andhra Pradesh. Keeping in view the domestic requirements for high yielding cotton varieties capable of spinning 60^s count yarn, Central Institute for Cotton Research, Regional Station, Coimbatore has developed a high yielding long staple *Gossypium hirsutum* cotton variety "Suraj" suitable for cultivation under irrigated conditions (Gururajan *et al*. 2008). This variety has shown superior performance in both central and south zone cotton growing states. Further, it has been found to give optimum yields under organic situations and also found suitable for high density planting system (HDPS).

Since cotton is processed into yarn in groups of fibres rather than as individual fibres, properties such as length variability, short fibre content, fineness, maturity and bundle strength among others influence the yarn quality and strength and resulting in textile products. Steady gains in longer fibre and higher bundle strength have been accomplished through breeding in 20^{th} century (May 1999).

Improvements in fibre quality have long been a primary objective of cotton breeders. One major obstacle for early breeders was the lack of reliable methods to measure fibre characteristics. Those methods have become available with the advent of HVI in late 1960s and AFIS in 1980s. During the last two decades, cotton breeders have used HVI (High Volume Instrument) as their primary and often sole source for fibre quality evaluation and using the HVI data for making plant selections, especially in India. However, earlier research recognized the need for additional information about AFIS properties and the potential role of AFIS in breeding programmes (Meredith *et al*. 1996). The intent of the AFIS design was not to correlate other fibre measurements with AFIS. It was designed to provide unique fibre data (Shofner *et al.* 1988). Fibre data generated by Advanced Fibre Information System technology is also now available to plant breeders, and provides additional information on length characteristics and fibre maturity (Kelly *et al*. 2013). Variation in fibre lengths and therefore shape of the distribution curves vary across cultivars with more uniform length and distribution desirable to reduce wastage in spinning and to produce better yarn (Smith *et al*. 2010).

The quantity of short fibres in a cotton sample is an important cotton quality parameter. Short cotton fibres have detrimental impacts on yarn production performance and yarn quality (Cai *et al*. 2011). There are different parameters for characterizing the amount of short fibres in a cotton sample. The most widely used parameter is short fibre content (SFC). It is a general practice in the textile industry to remove short immature fibres in the combing process to improve the fibre length distribution and tenacity.

The AFIS instrument individualizes and presents individual fibres to electro-optical sensors in order to measure fibre maturity, which is otherwise difficult in conventional method, and requires only very little quantity of lint for testing (Cai *et al*. 2011). Further, AFIS method of maturity measurements shows good correlations with the reference method.

Cotton fibre maturity, degree of secondary cell wall thickening relative to the perimeter, is one of the most important fibre quality and processing parameters of cotton (Paudel *et al*. 2013). Immature fibres result in low dye uptake, increased fibre breakage, fabric defects, and waste.

From these reports, it has been clearly indicated that short fibre content and immature fibre content play a major role in determining the quality of fibre and ultimately the yarn made out of these fibres. However, this information is not generated from HVI testing of fibre quality. Hence, a study was made to compare the fibre quality evaluation of the long staple cotton variety, Suraj using HVI and AFIS and to explore the possibility of selecting the variability existing within the population of variety with improved maturity and reduced short fibre content and the results are presented.

Material and Methods

The experimental material consists of breeder seed production plots of long staple cotton variety, Suraj at Central Institute for Cotton Research, Regional Station, Coimbatore during *kharif*, 2012. About 100 single plants were selected confirming the morphological characteristics of the variety. All these single plants were ginned to separate the lint from the seed and the characters like lint index, seed index and ginning outturn were calculated by following standard procedure using laboratory ginning machine. From these 100 single plants, 20 plants were short listed based on seed cotton yield and ginning parameters for fibre quality evaluation in both Advanced Fibre Information System (AFIS) and High Volume Instrument (HVI) at Central Institute for Research on Cotton Technology, Regional Quality Evaluation Unit, Coimbatore.

Data on fibre length by weight as well as by number (mm), upper quartile length by weight (mm), short fibre content (<12.7 mm) by weight as well as by number, 5% length by number (mm), fineness (mtex), maturity ratio, immature fibre content (%), fibre nep count per gram and their mean size (µm) and seed coat nep count per gram and their mean size (µm) were recorded in AFIS and 2.5 % span length (mm), Uniformity ratio (%), Micronaire (µg/inch) and tenacity at 3.2 mm gauge (g/tex) were recorded using HVI in ICC mode. These data were subjected to statistical calculations like range, standard deviation and coefficient of variation by following standard statistical procedures as per Johnson *et al.* (1955). Correlation between short fibre content (both by number and weight) and immature fibre content as well as between tenacity at 3.2 mm gauge and immature fibre content were worked out as per Falconer (1964).

Results and Discussion

Variability recorded in the 100 selected single plants of Suraj in respect of seed cotton yield and ginning characteristics is furnished in Table 1. Perusal of the data indicates that the coefficient of variability is high (14.0 %) in respect of seed cotton yield per plant, whereas, for ginning characteristics like seed index, lint index and ginning outturn the variability is limited. Similar results were presented by Neelima and Reddy (2008) and Rao and Reddy (2001). However, the variability for seed cotton yield within 20 single plants selected for fibre quality evaluation is narrow (8.9 %) when compared to the whole population of 100 plants (Table 2).

When the short listed 20 single plants of Suraj were subjected to fibre quality evaluation through AFIS, a narrow range of coefficient of variability (of less than 10 %) was noticed in characters like length (by weight), upper quartile length (by weight), length (by number), 5 % length (by number), fineness (mtex), maturity ratio and fibre neps. Comparatively larger extent of variability was noticed (of more than 10 %) for short fibre content (both by weight and by number), immature fibre content, fibre neps – count/g, seed coat neps – count/g and for seed coat neps – mean size. Perusal of data further indicated very high range of coefficient of variability (64 %) for seed coat neps in terms of count / gram of lint sample. However, this can be brought down by proper setting of ginning machine.

Short fibre content by weight ranges from 8.2 to 20.7 per cent with 20.8% coefficient of variability, whereas by number, it ranges from 26.3 to 48.0 per cent with 14.0 % coefficient of variability. Similarly, immature fibre content also showed larger coefficient of variability (16.7 %) with range being 5.7 to 11.0 per cent. This clearly indicates that there is large scope for improving the fibre quality of the long staple cotton variety Suraj, if we exercise selection properly based on AFIS data. In an earlier study by Kelly *et al*. (2013), yarn properties like tenacity, elongation, CV, thin places could be improved by selection exercised based on AFIS fibre quality evaluation and the resultant culture was better compared to commercial varieties.

However, the coefficient of variability for 2.5 % span length (mm), uniformity ratio (%), micronaire (µg/inch) and tenacity at 3.2 mm gauge (g/tex) was low when the fibre quality data was generated in these 20 selected plants in HVI (Table 2). This shows that variability estimates were narrow in the selected plants when fibre quality was analysed in HVI and exposes inherent weakness in analysing the fibre quality with HVI in Breeders' perspective. Originally, HVI was developed for the U. S. Department of Agriculture (USDA) in 1969 (Hsieh 1999) as a marketing tool to evaluate the quality of fibre in a bale of cotton. Though HVI is used widely for fibre quality evaluation, both for marketing as well as for breeding, there is still debate among breeders about its effectiveness for use as a breeding tool (Kelly *et al*. 2012). Earlier research also recognized the need for additional information and the potential role of AFIS in breeding programmes (Meredith *et al*. 1996).

It is important for breeders to understand the relationships that exist between overall fibre quality, specific fibre properties, and yarn quality. All of these factors interact and are critical to the development of cottons that can compete in a global market (Kelly *et al*. 2012 & 2013). When correlation coefficients were worked out between immature fibre content and short fibre content, both by number (r = 0.89) and by weight (r = 0.84), very high value was recorded indicating that by reducing short fibre content the immature fibre content can be reduced drastically (Figs. 1 & 2). Similarly, results of study by Kelly *et al*. (2012 & 2013) from different locations indicate significant impact of fibre maturity on various fibre and yarn properties. Further, the correlation between immature fibre content and tenacity at 3.2 mm gauge was negative (-0.91) and was high (Fig. 3). Earlier results also recognized fibre maturity as a component of fibre strength and high correlations between fibre maturity and short fibre content (Meredith *et al*. 1996; Ulloa 2006).

Mechanical damage in cotton fibre processing both shifts the fibre length distribution and alters its shape (Krifa, 2013). Fibre maturity plays a major role in determining the variability of the fibre length distribution modality at any processing stages. A mature cotton typically shows an extended intermediate damage, while an immature cotton will reach an advanced damage level from the early stages of mechanical processing.

Based on yield, ginning and fibre quality characteristics, the plant number 58 was found to combine ideally most of the parameters in desirable direction (Table 3). The plant number 22 recorded the highest value for short fibre content both by weight (20.7 %) and by number (48.0 %) and correspondingly had higher value of immature fibre content (10.7 %). The plant number 45 was the best for length by weight, upper quartile length as well as 5% length. The fibre length and maturity distribution in these select plants are shown in Figure 4.

The identified plants are being evaluated for performance of the progeny rows during the ensuing season. The results of the present study indicate the opportunity to the breeders to explore the hidden variability in fibre quality parameters, which were not estimated earlier using HVI, for improving the fibre quality and to reduce the fibre loss during mechanical processing in the spinning mills so as to fetch better price to the cultivators.

It is important for breeders to understand the relationships that exist between overall fibre quality, specific fibre properties, and yarn quality. All of these factors interact and are critical to the development of cottons that can compete in a global market. The quality parameters obtained from AFIS, in addition to HVI, helps the breeders for proper selection of single plants to improve the fibre quality attributes.

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Table 1. Variability for seed cotton yield and ginning characters in 100 selected single plants

Character	Mean	Minimum	Maximum	Standard Deviation	Coefficient of variability (%)
Seed cotton yield (g/plant)	130.1	92.0	214.0	18.2	14.0
Seed index (g)	6.4	5.6	7.4	0.5	7.9
Lint index (g)	10.3	9.4	11.9	0.7	6.9
Ginning outturn (%)	38.4	34.3	41.3	1.8	4.6

Table 2. Variability for fibre quality characters tested in AFIS in 20 selected single plants

Character	Mean	Minimum	Maximum	Standard Deviation	Coefficient of variability (%)
Method:AFIS					
Seed cotton yield (g/plant)	175.9	155.0	214.0	15.7	8.9
Length (by weight) (mm)	23.8	21.4	26.5	1.3	5.7
Upper Quartile Length (by weight) (mm)	31.1	28.8	34.2	1.4	4.4
Short Fibre Content (by weight) % <12.7 (mm)	14.7	8.2	20.7	3.0	20.8
Length (by number) (mm)	17.2	14.8	20.6	1.5	8.5
Short Fibre Content (by number) % <12.7 (mm)	38.8	26.3	48.0	5.4	14.0
5% Length (by number) (mm)	35.1	33.1	38.2	1.3	3.8
Fineness (mtex)	150.7	135.0	171.0	10.9	7.2
Maturity Ratio	0.9	0.8	1.0	0.0	4.7
Immature Fibre Content (%)	9.2	5.7	11.0	1.5	16.7
Fibre neps - Count/g	185.2	70.0	411.0	72.9	39.4
Fibre neps - Mean size (um)	656.5	598.0	714.0	30.5	4.7
Seed coat neps - Count/g	15.8	2.0	37.0	10.1	64.0
Seed coat neps - Mean size (µm)	1305.6	865.0	1775.0	221.7	17.0
Method: HVI					
2.5 % Span Length (mm)	32.5	30.6	34.7	0.8	2.4
Uniformity Ratio (%)	45.4	45.0	46.0	0.5	1.1
Micronaire (µg/inch)	3.8	3.1	4.7	0.4	9.4
Tenacity 3.2 mm (g/tex)	24.8	23.1	26.6	0.8	3.3

Table 3. Performance of select plants for yield and other parameters

Character	Method	Single Plant Number			
		22	45	56	58
Seed cotton yield (g/plant)	-	159	162	**214**	207
Seed index (g)	-	6.3	5.6	6.2	6.3
Lint index (g)	-	10.5	10.5	11.9	10.5
Ginning outturn (%)	-	37.5	34.8	34.3	37.5
Length (by weight) (mm)	AFIS	21.4	**26.5**	24.2	26.2
Upper Quartile Length (by weight) (mm)	AFIS	28.8	**34.2**	31.8	32.5
Short Fibre Content (by weight) % <12.7 (mm)	AFIS	20.7	11.3	14.2	**8.2**
Length (by number) (mm)	AFIS	14.8	19.1	17.3	**20.6**
Short Fibre Content (by number) % <12.7 (mm)	AFIS	48.0	35.2	39.6	**26.3**
5% Length (by number) (mm)	AFIS	33.1	**38.2**	35.5	35.9
Fineness (mtex)	AFIS	147	142	154	171
Maturity Ratio	AFIS	0.84	0.85	0.88	0.95
Immature Fibre Content (%)	AFIS	10.7	9.5	8.6	**5.7**
Fibre neps - Count/g	AFIS	155	212	193	104
Fibre neps - Mean size (um)	AFIS	661	644	638	**598**
Seed coat neps - Count/g	AFIS	10	6	16	20
Seed coat neps - Mean size (µm)	AFIS	865	1458	1403	1516
2.5 % Span Length (mm)	HVI	32.4	33.2	32.7	**34.7**
Uniformity Ratio (%)	HVI	46	45	45	45
Micronaire (µg/inch)	HVI	4.1	3.7	4.2	4.3
Tenacity 3.2 mm (g/tex)	HVI	23.6	24.9	25.2	**26.6**

Bold figures indicate the best values recorded in the desirable direction among the 20 selected plants

Figure 1. Relationship between short fibre content by number and immature fibre content (r = 0.89)

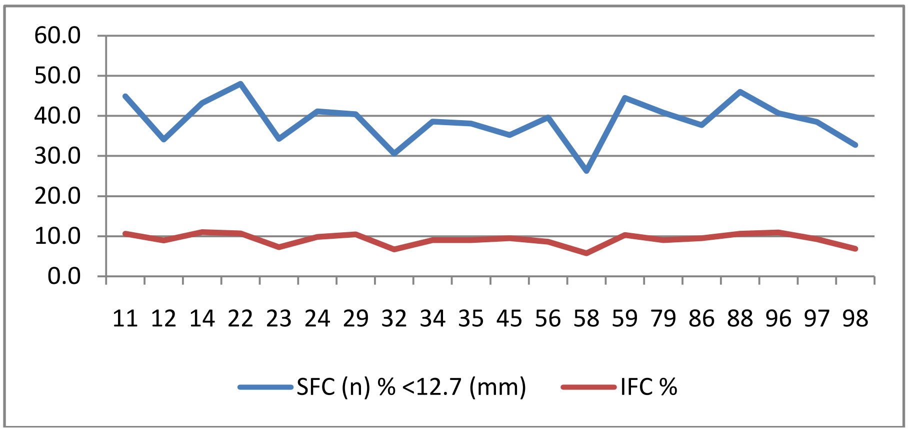


Figure 2. Relationship between short fibre content by weight and immature fibre content (r = 0.84)

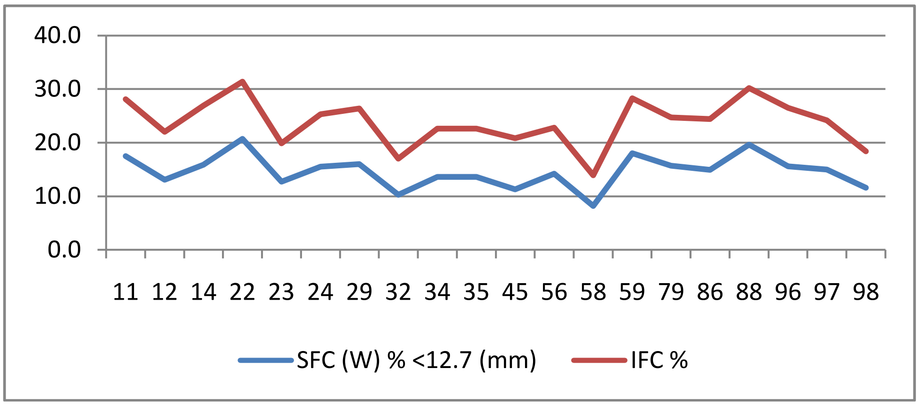


Figure 3. Relationship between immature fibre content and tenacity (r = -0.91)

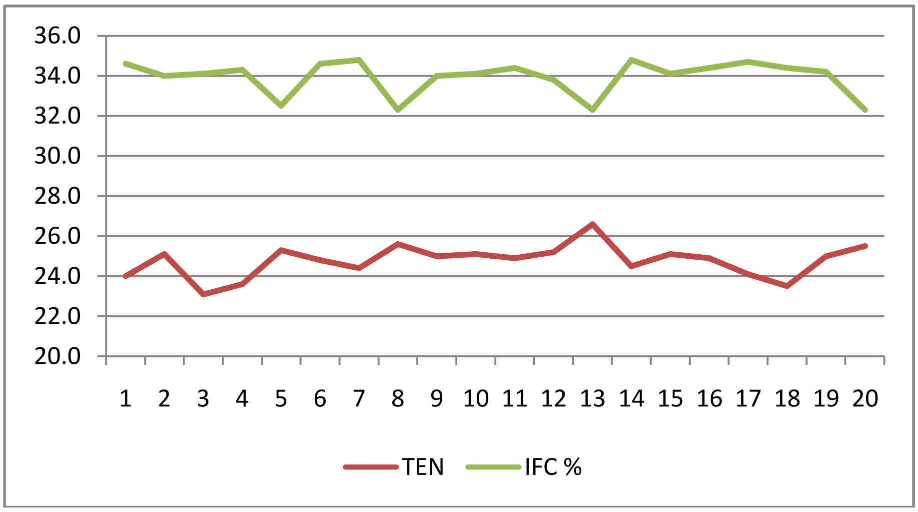
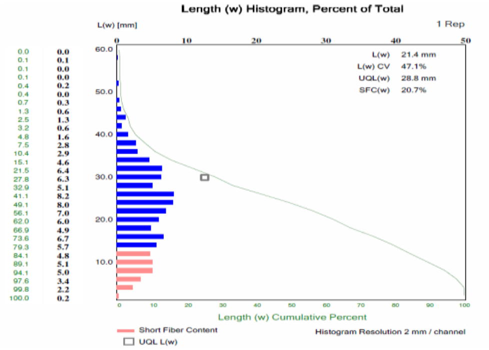


Figure 4. The fibre length and maturity distribution in selected single plants of Suraj



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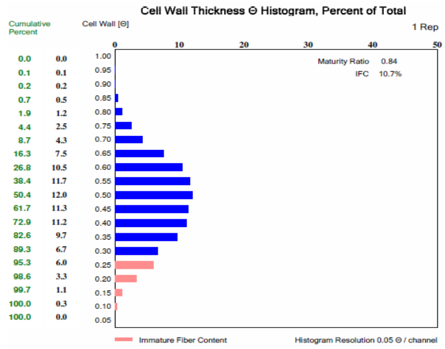

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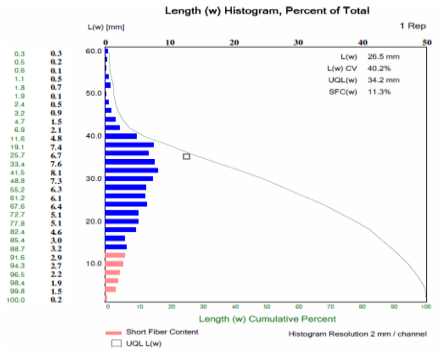

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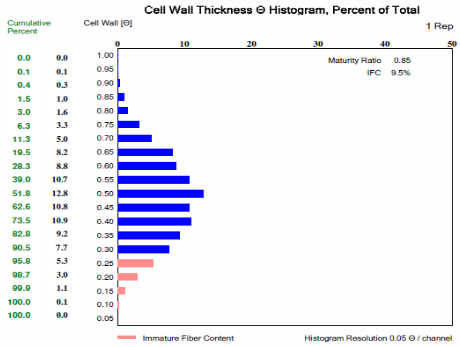

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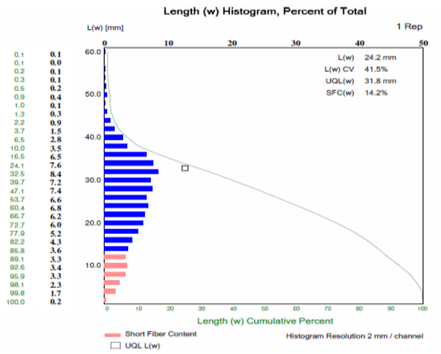

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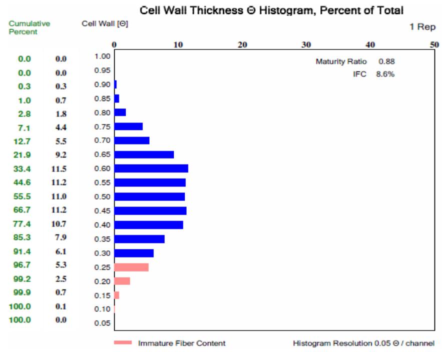

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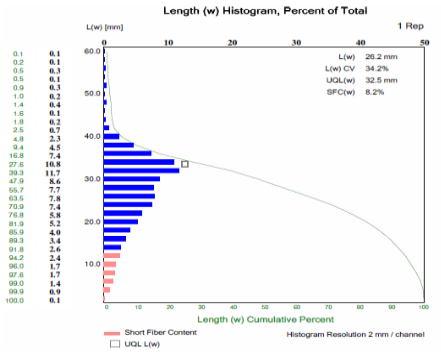

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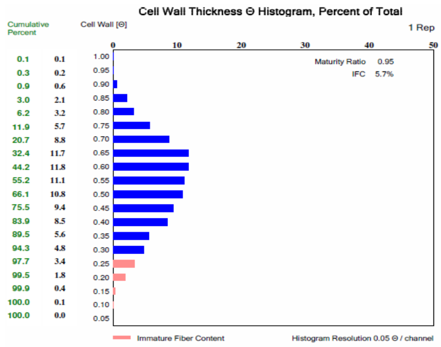

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