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Impact of Gin Saw-tooth Design on Fiber and Textile Processing Quality

S.E. Hughs* and Carlos B. Armijo

ABSTRACT

Toothed gin saws have been used to separate cotton fiber from the seed for more than 200 years. A scientific analysis of saw-tooth design has never been published and the optimum saw-tooth design has not been found. Initial laboratory ginning evaluations of some modern gin saw teeth have shown differences among designs in ginning rate, fiber length measurements, and textile processing quality. The saw gin stand used for testing was a Continental Double Eagle that had been cut down to 46 saws. Four different sets of 16-in diameter, commercially available replacement saws were obtained from independent suppliers. These four sets, along with the standard Continental saw set, were used for five test saw treatments. The test saws varied in the number of teeth per saw from 328 to 352. Testing of the five saw treatments was replicated four times for a total of 20 ginning lots. Each ginning lot was analyzed for raw fiber quality and textile spinning performance. Most of the raw fiber properties were not significantly affected by the saw treatments. However, HVI length and length uniformity after one stage of lint cleaning and seed cotton processing rate were significantly different among saw treatments. The ginning rates varied by 34% from the lowest to the highest at 75% gin stand motor load. The ginned fiber was processed into both open-end and ring-spun yarns. There were few significant differences among saw treatments for the open-end yarn, but there were significant differences for the ring-spun yarn in ends down (a measure of spinning efficiency), yarn evenness, and yarn strength. This indicates that gin saw-tooth design might significantly affect spinning efficiency and yarn quality. Research is currently being done to further understand how gin saw-tooth design affects ginned fiber quality and textile processing quality factors.

S.E. Hughs and C.B. Armijo, USDA, ARS, Southwestern Cotton Ginning Research Laboratory, 300 E. College Dr., P.O. Box 578, Mesilla Park, NM 88047
*Corresponding author: shughs@nmsu.edu

The history of saw-tooth design started with Eli Whitney's spike tooth gin patent on 14 March 1794 and Hodgen Holmes' circular toothed saw patent on 12 May 1796 (Bennett, 1960). Since these original patents, there have been many attempts by private individuals and gin machinery manufacturers to design the perfect gin saw tooth that was durable, resulted in high ginning capacity, and caused minimal fiber damage. The names of some of these teeth were wire teeth, sheathing wire claws, brier thorn spikes, gin saw with buckhorn needles, and wire needle teeth. The impetus behind the design of these gin saw teeth is unknown and their picturesque names have faded into history. By 1935, these earlier tooth designs had been abandoned and saw-tooth design had evolved to include a few designs that varied from approximately 32° to 48° in saw pitch angle and saw back designs of straight, moderate roach (slightly curved back), or heavy roach (more curve) (Bennett, 1960). The curved or roach-back designs were to give the tooth more mechanical strength than the simpler straight-backed tooth. These designs probably evolved more out of practical experience as to tooth wear, some subjective evaluation of ginning rate, and overall tooth life rather than organized research.

There have been some attempts by the USDA to evaluate scientifically gin saw-tooth designs. In some of the first work by the USDA, Martin and Stedronsky (1939) evaluated saw-tooth designs, saw diameters, and numbers of teeth per saw. They found that the number of teeth, pitch of the tooth, and tooth shape all affected ginning capacity. Griffin and McCaskill (1969) reported on a number of ginning experiments conducted at Stoneville, MS. There were several failures, but their positive conclusion was that the number of teeth on a saw should be limited to approximately 264 teeth or less on a 30.5-cm (12-in.) gin saw. Mayfield and McCaskill (1970) evaluated a straight-back and a moderately roached-back tooth design. Their primary conclusion was that the roached-back tooth caused significantly less seed damage than did the straight-back tooth. Columbus et al. (1994) made recommendations as to the maintenance and adjustments of various gin stands and their saws, but made no judgments as to differences in saw-tooth design, if any, that existed between the various gin saw manufacturers. Vandergriff (1997) noted that current saw thickness varied from 0.914 to 1.143 mm (0.036 to 0.045 in.) depending on the gin machinery manufacturer, and gave some of the current tooth dimensions. He also noted that the pitch angle of modern 30.5-cm (12-in.) gin saws has been nearly standardized and that there is some variation in number of teeth per saw.

Mayfield and McCaskill (1970) stated, "A complete analysis of the effects of each individual property of a saw on its performance has never been attempted. Saws have been designed at random and then their performance has been tested. Thus, no one has ever been positive that the best saw-tooth design has been found". This statement is still true today.

Hughs and McAlister (2004) reported on preliminary research that investigated raw fiber differences due to variety, ginning rib design, and gin saw-tooth design. They found that gin saw-tooth design resulted in ginned fiber quality differences. Hughs and Armijo (2013) released a preliminary report on a subsequent ginning test that investigated the effects of gin saw design on raw fiber quality as well as textile processing quality. Their tests found that gin saw-tooth design affected not only raw fiber quality but also textile processing quality. The objective of this research was to test current gin saw-tooth designs and evaluate their effects on fiber quality, ginning performance parameters, and textile processing quality.

MATERIALS AND METHODS

The gin stand used for testing was a Continental Double Eagle (Continental Eagle Corp., Prattville, AL) that had been cut down to 46 saws. Four different sets of 16-in diameter, commercially available replacement saws for the Double Eagle gin stand were obtained from suppliers other than Continental. These four saw sets, along with the standard Continental saw set, were used for the five test saw treatments. All of the saw sets were manufactured to be interchangeable for the standard 16-in diameter Continental saws. The noticeable difference between saw sets was that the number of teeth per saw varied from 328 to 352. Each saw set was stacked on a separate saw mandrel for rapid ease of installation and removal of different saws during the test. Each saw design was arbitrarily assigned an ID number from 1 to 5. Each saw mandrel was randomly installed for each of the five gin saw test conditions. A limiting factor of saw mandrel randomization was that although numbers were assigned randomly to each mandrel, once each mandrel was installed, all four replications were run sequentially for that mandrel. The difficulty of removal, installation, and adjustment of a given mandrel after each ginning lot and the probably of saw damage were judged too great to do otherwise. As each set of saws was mounted and adjusted in the gin stand, the relationship of the saw-teeth leading edges to the ginning ribs was checked randomly at nine places along the saw mandrel, as recommended by Columbus et al. (1994). All five sets of test saws met the criteria for the general industry standards of saw-tooth leading edge to ginning rib at the ginning point.

The test cotton was a Delta Pine upland variety, typically grown in the Mesilla Valley of New Mexico using normal production practices for the area. All seed cotton came from one module that had been spindle-picker harvested after frost from a uniform field. For testing, the seed cotton was transferred to three separate trailers that were then randomly chosen for the ginning test lots. The assumption was that randomizing the input test seed cotton would compensate for not being able to completely randomize all of the ginning lots.

Testing of the five gin saws was replicated four times resulting in a total of 20 ginning lots. Each ginning lot weighed 204 kg (450 lb) and was processed through seed cotton cleaning using two six-cylinder cleaners and one stick machine. No drying was needed on any of the ginning lots as the seed cotton had been harvested dry in the Mesilla Valley of New Mexico and then stored for a long period in trailers under covered storage. The seed cotton was ginned on the 46-saw gin stand, followed by one lint cleaner and the bale press. The gin stand was operated so as to maintain the same motor horsepower (approximately 75% full load) for each ginning lot throughout the test. Gin stand motor load was maintained by adjusting the gin stand feeder seed cotton feed rate for each test saw. Seed cotton samples were taken at the trailer and the gin stand feeder apron. Ginned lint samples were taken after the gin stand and after lint cleaning for moisture, trash, and raw fiber quality analysis. The ginned lint lots, approximately 68 kg (150 lbs) each, were baled and sent to the USDA-ARS, Clemson Pilot Spinning Plant, Clemson, SC for fiber analysis and textile processing.

Raw ginned fiber analysis consisted of High Volume Instrument (HVI, Uster Technologies, Uster, Switzerland), Advanced Fiber Information System (AFIS, Uster Technologies, Uster, Switzerland), and Shirley Analyzer tests. Textile processing consisted of both open-end spinning (20 singles yarn count) and ring spinning (35 singles yarn count), and knitted fabric that was scoured and dyed for white speck count. Each ginning lot was split into two lots of approximately 34 kg (75 lbs) each for open-end and ring spinning. All spinning lots were carded at a rate of 68 kg (150 lbs) per hour with the ring-spun lots also being combed to produce 35-g sliver for spinning. Yarn testing included ends down, yarn evenness, yarn strength, and carding waste. Fabric testing only included counting of dying imperfections commonly known as white specks.

Analysis of variance was performed with the General Linear Model (GLM) of SAS at the 5% level of significance (version 9.1, SAS Institute, Inc., Cary, NC), and differences among main effect treatment means were tested with Duncan's new multiple-range test.

RESULTS AND DISCUSSION

An interesting result is shown in Table 1 with the average ginning rate in terms of the average weight of seed cotton processed through the saw gin stand per minute. The gin stand was operated at a constant 75% average motor load at all times, but many of the saw treatments were significantly different from each other and varied from a low of 30.4 kg (67 lb) to a high of 40.7 kg (90 lb) of seed cotton per minute. The saw with the highest ginning rate had the fewest number of teeth, 328. The saw with the second highest ginning rate had the same number of teeth, 352, as did the saw with the lowest ginning rate. Hughs and McAlister (2004) showed almost the same results for seed cotton processing rate using a different upland cotton but using the same test saws that were used for this test. When viewed under a magnifying glass, the saw teeth of the five test saws were somewhat different from each other in tooth shape (Fig. 1). Saw #2 is the standard Continental saw tooth and the other four are from other suppliers. The saw numbers in Fig. 1 correspond to the test treatment number. In some way, unknown at the present, the saw-tooth shape has a more significant effect on seed cotton ginning rate than does the total number of teeth per saw.

Table 1. Average gin saw processing performance and nep count[z]

Saw Number	Number of Teeth per Saw	Kg (lbs) Seed Cotton per Minute	AFIS Nep Count, no./g	
			Before Lint Cleaner	After Lint Cleaner
1	328	40.7 (89.8) a	214 c	320 c
2	352	36.7 (81.0) b	220 bc	326 bc
3	352	36.4 (80.2) b	248 abc	351 abc
4	330	32.4 (71.5) c	268 a	371 a
5	352	30.4 (67.0) d	256 ab	358 ab

[z] Means followed by a different letter are significantly different at the 5% level by Duncan's new multiple-range test.

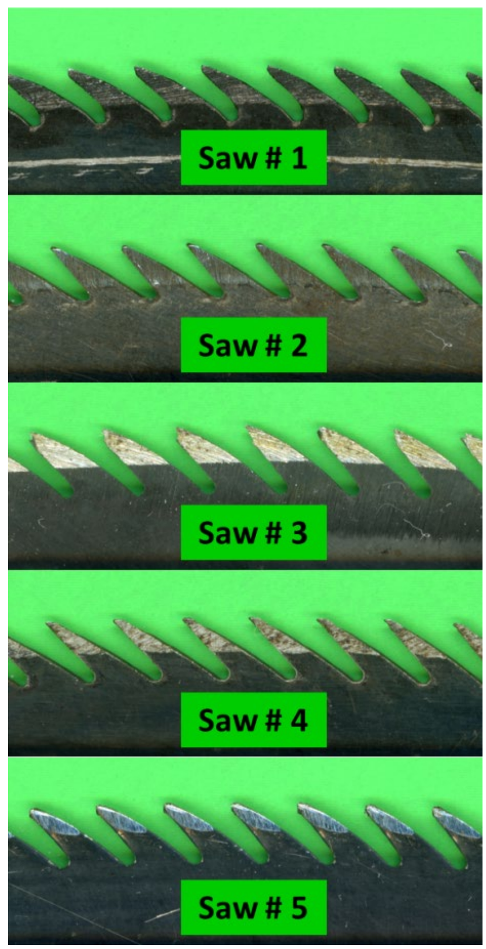

Figure 1. Profiles of test saw teeth.

Table 1 also shows an interesting difference in nep count before and after lint cleaning. The saws with the fewest teeth (numbers 1 and 4) also had the lowest and the highest AFIS nep counts, respectively, with the other three saws having intermediate counts. Hughs and McAlister (2004) showed the same trend of nep count increasing after lint cleaning, but they did not show a significant difference in nep count between saws. Not shown in Table 1 are the average moisture contents for the seed cotton and lint for each test. Moisture content differences could contribute to differing nep levels. However, seed cotton moisture averaged 6.8% (dry base) and lint moisture averaged 5.9% (dry base) across treatments, with no statistical difference in moisture content between test treatments. These moisture levels are in the recommended range for ginning cotton and therefore, it can be assumed that moisture level did not contribute to significant differences in nep levels between test saws. Significant differences in nep levels shown in Table 1 from this test and not shown in earlier tests by Hughs and McAlister (2004) might be a factor of this test cotton being grown in a different year, or that it was a different variety than used in the earlier test.

HVI average length and length uniformity before and after one stage of lint cleaning are shown in Table 2. The trends are the same for both measurements as those reported by Hughs and McAlister (2004); however, the only significant difference between saws for this test was fiber length and length uniformity after lint cleaning. The saw with the significantly highest seed cotton ginning rate had the significantly shortest length but one of the higher uniformities, although the differences in both cases were relatively small. The average AFIS raw fiber length parameters shown in Table 3 did not result in any significant differences before or after lint cleaning between saw-tooth designs. The earlier test by Hughs and McAlister (2004) showed significant differences in these same AFIS measurements after lint cleaning. Even though the average AFIS measurements were not significantly different between saws, the overall trends are what would be expected with both length and length uniformity being decreased by lint cleaning.

Table 2. Average raw fiber HVI data[z]

Saw Number	Length, cm (in)		Length Uniformity, %	
	Before Lint Cleaner	After Lint Cleaner	Before Lint Cleaner	After Lint Cleaner
1	2.97 (1.17) a	2.84 (1.12) b	81.2 a	80.3 a
2	2.97 (1.17) a	2.90 (1.14) a	81.1 a	79.6 b
3	2.95 (1.16) a	2.92 (1.15) a	81.0 a	80.3 a
4	2.97 (1.17) a	2.92 (1.15) a	81.1 a	80.1 ab
5	2.97 (1.17) a	2.90 (1.14) a	81.6 a	80.0 ab

[z] Means followed by a different letter are significantly different at the 5% level by Duncan's new multiple-range test.

Table 3. Average raw fiber AFIS length[z]

Saw Number	Upper-Quartile Length (w), cm (in)		Short Fiber Content (w), %	
	Before Lint Cleaner	After Lint Cleaner	Before Lint Cleaner	After Lint Cleaner
1	3.10 (1.22) a	3.02 (1.19) a	11.6 a	14.2 a
2	3.12 (1.23) a	3.02 (1.19) a	11.6 a	14.2 a
3	3.05 (1.20) a	3.02 (1.19) a	12.8 a	14.3 a
4	3.07 (1.21) a	3.02 (1.19) a	13.4 a	14.2 a
5	3.07 (1.21) a	3.05 (1.20) a	13.0 a	13.5 a

[z] Means followed by a different letter are significantly different at the 5% level by Duncan's new multiple-range test.

The ginned fiber was then processed into both open-end and ring-spun yarns. The only significant differences between gin saw treatments for the open-end yarn were single strand elongation and coefficient of variation of drawing sliver. These measurements are relatively minor factors and so these results are not shown. It is speculated that few differences were found in the open-end yarn because the open-end yarn spinning system is used to make relatively coarse yarn counts. These coarser yarns are less sensitive to raw fiber length parameters than are finer ring-spun yarns.

There were several significant differences in spinning parameters and yarn properties for the ring-spun yarn. Table 4 shows some of the more important ring-spun yarn differences with ends down being one of the more important to the spinner. Table 4 shows that the gin saw (#1) with the highest seed cotton processing rate had significantly higher ends down compared to the other four saws. The saw with the lowest seed cotton ginning rate (#5) had one of the lowest number of ends down per 1000 spinning hours. Another gin saw (#2), which had an intermediate seed cotton processing rate, also was equivalent to gin saw #5 in the lower number of ends down. Ends down are a measure of spinning efficiency with the lower the number meaning higher spinning efficiency, which equates to higher productivity and ultimately higher profitability to the spinner. This test indicates that gin saw-tooth design has a significant effect on spinning efficiency at the textile mill. Table 4 also shows that the higher variation in yarn strength and yarn evenness, as indicated by yarn neps, follows the same pattern as ends down for the five test saws. The higher the variation in yarn strength and the more neps, the more ends down.

Table 4. Average ring-spun 35/1 yarn quality averages[z]

Saw Number	Ends Down, no./1000 hrs	Singles Strength, CV	Yarn Neps/914.4 m (1000 yd)
1	87.0 a	11.9 a	1070 a
2	32.8 b	11.1 b	930 b
3	66.5 ab	11.2 b	1054 a
4	51.8 ab	11.6 a	1042 a
5	29.5 b	10.6 c	898 b

[z] Means followed by a different letter are significantly different at the 5% level by Duncan's new multiple-range test.

Table 5 shows some additional measures of yarn evenness where there are also significant differences between the five gin saws. In all cases for the measurements of yarn; thick places, thin places, and coefficient of variation (CV) of yarn irregularity, the gin saw that had the lowest number of ends down also resulted in significantly more uniform yarn. Conversely the gin saw with the highest numbers of ends down resulted in higher yarn irregularity.

Table 5. Average ring-spun 35/1 evenness values[z]

Saw Number	Thick Places, no./914.4 m (1000 yds)	Thin Places, no./914.4 m (1000 yds)	Yarn Irregularity, CV
1	2268 a	859 a	24.1 a
2	2075 cd	711 cd	23.4 cd
3	2150 bc	748 bc	23.6 cb
4	2177 b	789 b	23.7 b
5	2002 d	666 d	23.2 d

[z] Means followed by a different letter are significantly different at the 5% level by Duncan's new multiple-range test.

Table 6 shows additional significantly different quality measurements for the ring-spun yarn. These data do not show as clear a pattern as do the data in Tables 4 and 5, but the gin saw with the highest number of ends down had significantly higher major yarn faults as well as intermediate length and short fiber content after combing (finish drawing). The upper-quartile length and short fiber percentage differences, although significant, are not large between the different tests. Raw fiber length measurements discussed earlier were not significantly different for the most part and so it is difficult to ascribe significantly different yarn evenness and processing faults to raw fiber length differences at this point.

Table 6. Average ring spinning yarn quality values[z]

Saw Number	USTER Classimat Major Faults, #/914.4 m (1000 yds)	AFIS Finish Drawing UQL, cm (in)	AFIS Finish Drawing Short Fiber Content, %
1	13.5 a	3.068 (1.208) bc	14.1 a
2	4.0 b	3.112 (1.225) a	12.7 b
3	8.5 ab	3.078 (1.212) abc	14.2 a
4	6.3 b	3.043 (1.198) c	14.7 a
5	8.0 b	3.086 (1.215) ab	13.7 ab

[z] Means followed by a different letter are significantly different at the 5% level by Duncan's new multiple-range test.

The ring-spun yarns were knit into fabric and dyed to test for their level of white specks or dying imperfections. The level of white specks for the dyed fabrics was low and not significantly different between any of the five gin saws (data not shown). No other fabric properties were tested.

SUMMARY

This is a report of the test results of gin processing of a uniform upland cotton using five different gin saw designs all manufactured to be compatible with a Continental Double Eagle saw gin stand. Specific quality measurements were taken at each processing step including ginning, yarn spinning, and dyed cloth. Significant observations from the test are as follows:

1. The major difference in ginning performance between the five different saw sets was that, at constant gin-stand motor load, their seed cotton processing rate varied by as much as 34% from lowest to highest.
2. The number of teeth per saw ranged from 328 to 352; the saw with the fewest teeth had the highest seed cotton ginning rate and one of the saws with the most teeth had the lowest ginning rate.
3. There were almost no significant differences in raw ginned fiber quality as measured by the HVI or AFIS.
4. There were no important significant differences in 20/1 open-end yarn processing parameters or yarn quality from the test cottons produced by the five different gin saw designs.
5. There were important differences in 35/1 ring-spun yarns made from test cottons ginned by

the five different gin saw designs. These differences included textile spinning efficiency, yarn evenness, and yarn strength.

6. There were no significant differences in dyeing imperfections of knitted cloth made from either the open-end or the ring-spun yarns.

In summary, there were important and significant differences between gin saws of different designs made for the same gin stand. These differences are related to processing efficiency in both the ginning process as well as the spinning process for higher quality ring-spun yarns. In addition, yarn quality for ring-spun yarns, as measured by yarn evenness, strength, and yarn faults, was affected by the design of the saw tooth used to produce the raw ginned fiber. Further testing needs to be done to determine what saw-tooth design parameters contribute to the significantly different ginning and textile processing performance.

DISCLAIMER

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REFERENCES

Bennett, C.A. 1960. Saw and toothed cotton ginning developments. Texas Cotton Ginners Association, Dallas, TX.

Columbus, E.P, D.W. Van Doorn, B.M. Norman, and R.M. Sutton. 1994. Gin stands. p. 90–102 *In* W.S. Anthony andW.D.Mayfield (eds). Cotton Ginners Handbook. USDA-ARS Handbook 503, Washington, DC.

Griffin, A.C., and O.L. McCaskill. 1969. Gin-stand research at Stoneville, Mississippi: 1956-66. USDA Tech. Bull. 1407. Washington, DC.

Hughs, S.E., and C.B. Armijo. 2013. Impact of gin saw tooth design on textile processing. p. 988–989 *In* Proc. Beltwide Cotton Conf., San Antonio, TX. 7-10 Jan. Natl. Cotton Counc. Am., Memphis, TN.

Hughs, E., and D. McAlister. 2004. Evaluation of selected gin saw tooth designs. p. 969–972 *In* Proc Beltwide Cotton Conf., San Antonio, TX. 5-9 Jan.. Natl. Cotton Counc. Am., Memphis, TN.

Martin, W.J., and V.L. Stedronsky. 1939. Effects of variations in design of gin-saw teeth on lint quality and ginning efficiency. USDA, Agr. Market. Serv. Bur. Agr. Chem. Eng. Washington, DC.

Mayfield, W.D., and O.L. McCaskill. 1970. An evaluation of the performance of two gin saw tooth designs. USDA, ARS, ARS 42-175. Washington, DC.

Vandergriff, A.L. 1997. Cotton Ginning—an Entrepreneur's Story. Texas Tech Univ. Press, Lubbock, TX.