EFFECTS OF LINT CLEANING ON LINT TRASH PARTICLE SIZE DISTRIBUTION

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Abstract

Cotton quality trash measurements used today typically yield a single value for trash parameters for a lint sample (i.e. High Volume Instrument – percent area; Advanced Fiber Information System – total count, trash size, dust count, trash count, and visible foreign matter). A Cotton Trash Identification System (CTIS), developed at the USDA-ARS Southwestern Cotton Ginning Research Laboratory, was used to identify and size trash objects in the lint samples collected before and after lint cleaning, as part of a two-year beltwide commercial cotton gin sampling project. The CTIS trash categorizations were used to develop particle size distributions (PSD) for the lint samples. These PSD were then compared to assess the effect of lint cleaning. Also, different probability density functions were explored to characterize the shape of the lint trash PSD. Typical of standard foreign matter analyses, foreign matter content was decreased by lint cleaning. Further, the data suggested that foreign matter was reduced for all particle sizes, but not at the same rate for all particles sizes. Surprisingly, though total foreign matter levels, both count and area, and maximum particle size decreased with lint cleaning, the average particle size increased.

Introduction

Saw-type lint cleaners are used at gins to reduce foreign matter content after ginning (Mangialardi et al., 1994). They work to remove foreign matter from lint through the combined action of centrifugal force and scrubbing of the fibers against steel grid bars (Figure 1).

Small trash and dust particles can cause problems in the textile mill. Generally, dust in ginned lint is defined as particles less than 500 µm and trash as particles greater than 500 µm. Typical measurements used to describe the levels of foreign matter in cotton lint come from the High Volume Instrument (HVI): percent area and the Advanced Fiber Information System (AFIS): foreign matter count, dust count, trash count, and visible foreign matter.

Typical results from fiber analyses (Figure 2) show that foreign matter count and total amount (based on visual area measurements and weight) decreases with one and two lint cleanings. These fiber foreign matter measurements are bulk measures for the sample of cotton analyzed. Some foreign matter measurements are based on raw measurements of individual particles that are lost in the averaging calculations and may otherwise provide insight into cotton foreign matter removal mechanisms. Anthony (2002) analyzed AFIS data for many different seed-cotton and lint cleaning machinery sequences and found that more extensive seed-cotton and lint cleaning reduced levels of trash, including dust (smaller than 500 µm) and trash (larger than 500 µm). Anthony's analysis of particle size distributions, based on AFIS measurements for cotton lint with no lint cleaning and lint cleaned with two lint cleaners, showed that two lint cleaners reduced the number of particles in all sizes and removed all larger particles (> 1800 µm).

This research was undertaken to better understand how lint cleaning affects, not just a single value for trash content, but the shape and scale of the trash particle size distribution in ginned cotton lint. The main goals of the research were:

1. To analyze cotton lint samples before and after lint cleaning, in order to identify foreign matter by size.
2. To generate descriptive statistics and particle size distributions, to describe the lint foreign matter content.

3. To identify a probability density function that closely fits typical cotton lint foreign matter particle size distributions.

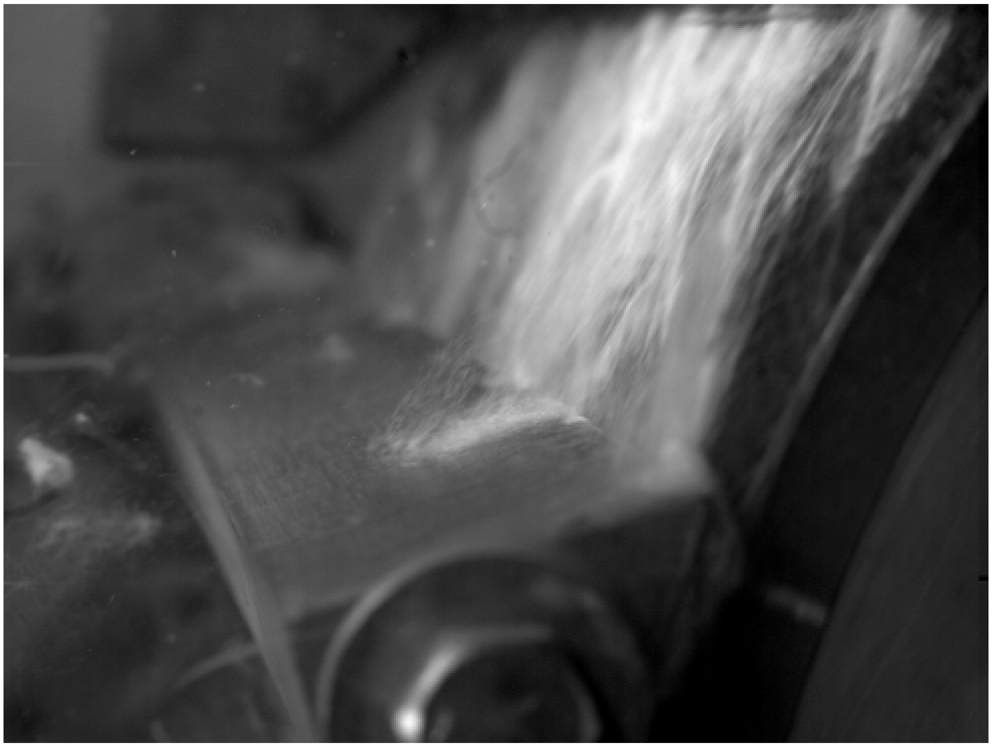


Figure 1. Fibers scrubbing across a lint cleaner grid bar.

Materials and Methods

Cotton lint samples used for this research were collected from 13 gins, over two years during a previous Cotton Incorporated supported beltwide cotton quality, gin sampling study (Whitelock et al., 2007a and b). The samples were taken from the conveying air duct before lint cleaning behind the gin stand, after the 1st lint cleaner and after the 2nd lint cleaner. Five replicate samples were taken at each location during the ginning of a single module, to ensure that the cotton was uniform. Each gin was sampled at least twice and up to five times during the season, depending on the total number of bales ginned. As a consequence of the magnitude of the sampling project, there were over 800 samples for analysis with 15 different varieties represented.

The cotton samples were analyzed at the USDA-ARS Southwestern Cotton Ginning Research Laboratory (SWCGRL), with a system developed in-house for the acquisition and processing of cotton images called Cotton Trash Identification System (CTIS). The system uses digital cameras or scanners for the acquisition of cotton images. The system utilizes the CottonEye image processing software developed at the SWCGRL, Matrox Imaging Library (MIL Ver. 7.5) image processing software, and other custom algorithms to process cotton images to identify trash. The acquired images were processed for trash identification and categorization by size categories. The system reports the histogram distribution of both dust (< 500 microns) and trash (≥ 500 microns) objects in 50 micron increments (up to 2000 microns); similar to the trash distribution histograms provided by AFIS. For this project, a scanner based configuration of CTIS, incorporating an EPSON perfection 3170 photo scanner was used. Scans of three different 5 in. x 5 in. areas of each sample were taken at 400 dpi resolution. At that resolution, the smallest recognizable particle of one pixel in size, would have actual dimensions of about 63µm x 63 µm or 70 µm equivalent diameter. Each image was analyzed with the CottonEye software to identify non-lint objects, categorize those objects, and develop histograms and descriptive statistics for the average of the three images taken per each sample. Figure 3 shows examples of images taken with CTIS and examples of binary images after the trash particles have been identified for samples before and after lint cleaning. Notice lint discolorations and shadows are mostly ignored by CTIS.

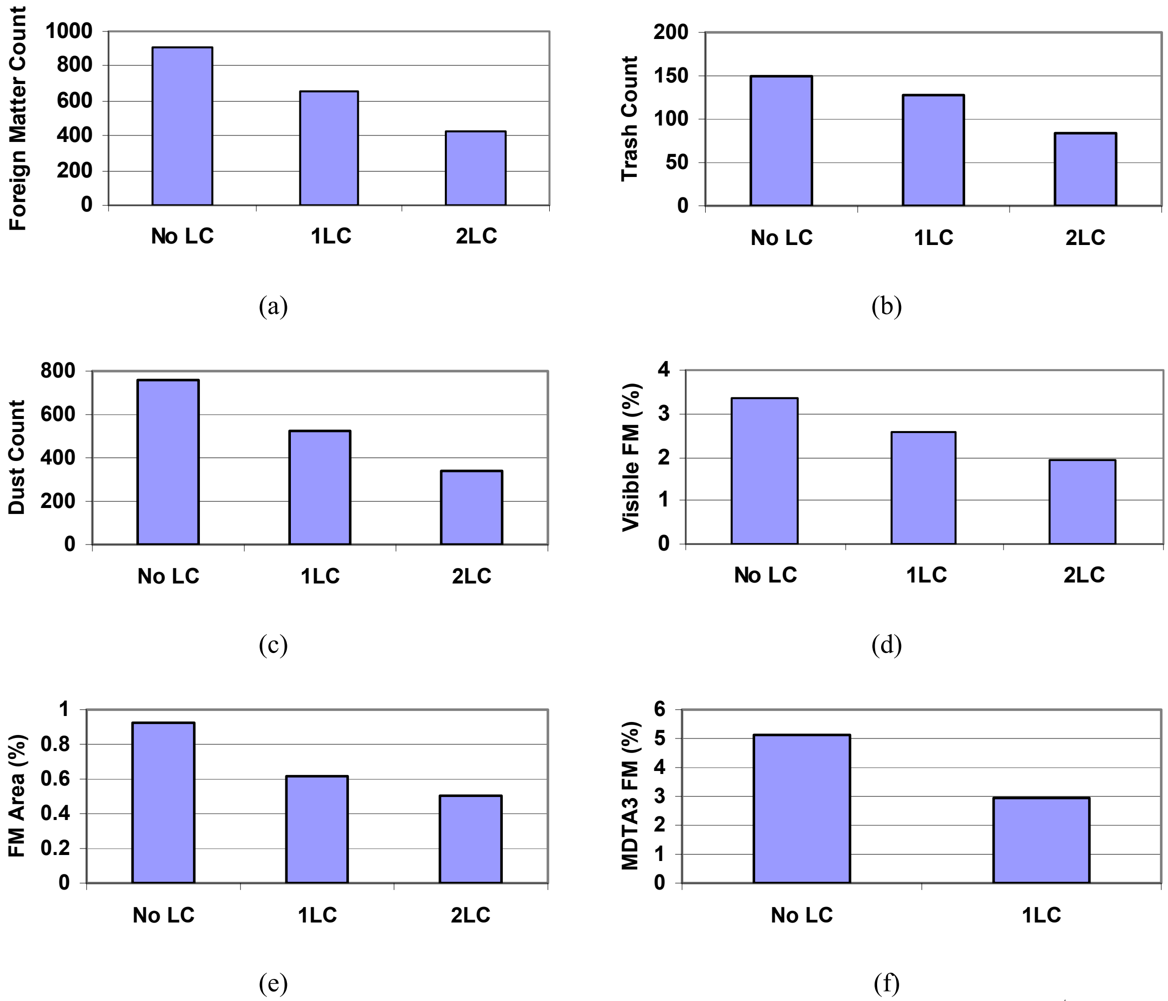
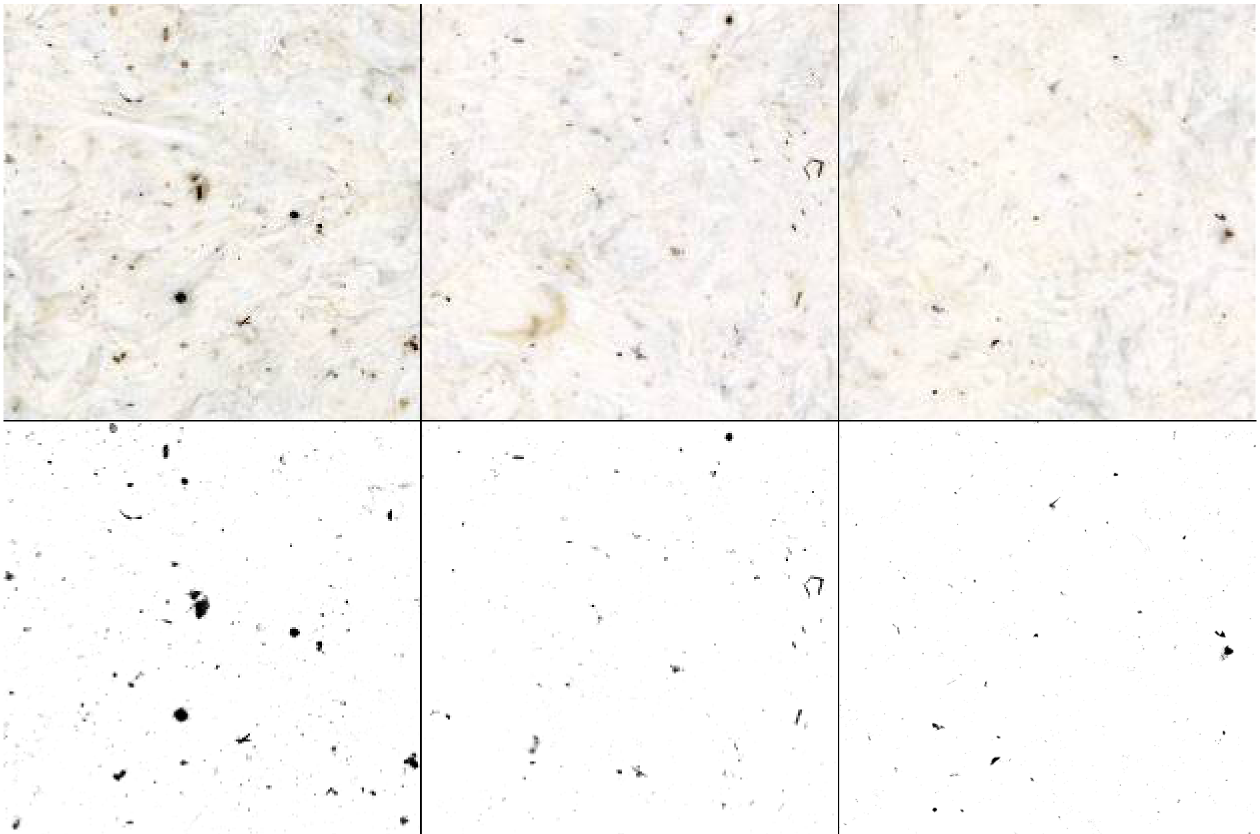


Figure 2. Typical cotton lint foreign matter measurements before lint cleaning (No LC) and after the 1st (1LC) and 2nd (2LC) lint cleaners: (a) AFIS Foreign Matter Count, (b) AFIS Trash Count, (c) AFIS Dust Count, (d) AFIS Percent Visible Foreign Matter, (e) HVI Foreign Matter Area, and (f) MDTA3 Foreign Matter.

Results and Discussion

Analyses and results for this manuscript are limited to samples from a single gin, but are representative of most gin data analyzed to date.

Results of the analyses revealed some interesting details about the effects of lint cleaners on cotton lint foreign matter. Bulk measures calculated from the CTIS data, showed similar trends as those measured by AFIS and HVI. Foreign matter levels, both area and count, went down with lint cleaning (Table 1). Dust particle (<500 µm) counts were greater than trash (>500 µm) counts and decreased at a greater rate with lint cleaning. Note that while the amount of foreign matter decreased with lint cleaning, the average particle size increased from 177 µm to 195 µm. This is further illustrated by the quantities in Table 1. For all lint cleaning levels the median particle size was 101 µm, but 75% of the particles before lint cleaning were ≤ 143 µm and 75% of the 1st and 2nd lint cleaner particles were ≤ 160 µm. The 90th percentile particle size for the 1st lint cleaner was smaller than that for the 2nd lint cleaner. Interestingly, the particle sizes at the highest percentiles decreased with lint cleaning. For example the maximum particle size ranged from 9980 µm before lint cleaning to 4464 µm after the 2nd lint cleaner.



Before Lint Cleaning | After 1st Lint Cleaner | After 2nd Lint Cleaner

Figure 3. Raw (top row) and segmented binary (bottom row) images of cotton lint before lint cleaning, after 1st lint cleaner, and 2nd lint cleaner.

Particle size distributions illustrate and shed light on the results in Table 1. Figure 4 shows that the number of particles was reduced by lint cleaning in almost every size category, the majority of particles before and after lint cleaning fell in the dust category of smaller than 500 µm, and size categories larger than about 1300 µm averaged less than one particle (except for a small number in the greater than 2000 µm category). Similarly, the particle size distribution based on percentage of the total foreign matter count (Figure 5) shows that there were fewer particles in the larger size categories. Also, the percentages of particles for a particular size were different among lint cleaning levels. For example, the percent of total particles in the 50 – 100 µm size ranged from 41 to 32% for before lint cleaning to after the 2nd lint cleaner. This suggests that foreign matter was not reduced by lint cleaning at the same rate for all sizes. In fact, for some size categories, Figure 5 shows that the percentage of foreign matter particles increased with lint cleaning.

Several probability density functions were fit to the foreign matter particle size distributions (Figure 6). These analyses suggested that the Weibull or Gamma functions, with thresholds near the value for the smallest particle detected may fit the distributions well. More work with the data from the remaining samples is needed to better identify the function with the best fit.

Summary

Samples of ginned lint were analyzed with an imaging system to better understand the effect of lint cleaning on foreign matter particle size. As is typically seen from foreign matter analyses, foreign matter content was decreased by lint cleaning. This was shown to be true for all sizes of particles. The data also suggested that foreign matter was not reduced at the same rate for all particles sizes. Also, though total foreign matter levels, both count and area, and maximum particle size decreased with lint cleaning, the average particle size increased. The Weibull and Gamma probability density functions were identified as possible candidates to fit the particle size distributions. These results highlight the need for further analyses of the foreign matter particle size distributions to better understand the interaction between particle size and different levels of lint cleaning.

Table 1. Foreign matter statistics generated from the CTIS system data for a selected gin.

Foreign Matter Statistic	Before Lint Cleaning	After 1st Lint Cleaner	After 2nd Lint Cleaner
Foreign Matter Area (pixels)	40666	34081	10521
Foreign Matter Area (%)	1.02	0.85	0.26
Total Foreign Matter Count	1470	1057	371
Dust (<500 µm) Count	1398	996	346
Trash (>500 µm) Count	71	61	25
Foreign Matter Size			
Average (µm)	177	190	195
Standard Deviation (µm)	334	360	328
Standard Error of Mean	5.04	6.39	9.84
Upper 95% C.L. Mean (µm)	184	203	214
Lower 95% C.L. Mean (µm)	164	178	175
Quantiles	------------------------------ Particle Size (µm) ----------------------------		
100% Maximum	9980	6207	4464
99.5%	2142	2717	2417
97.5%	930	1052	1025
90%	287	304	362
75% Quartile	143	160	160
50% Median	101	101	101
25% Quartile	72	72	72
10%	72	72	72
2.5%	72	72	72
0.5%	72	72	72
0.0% Minimum	72	72	72

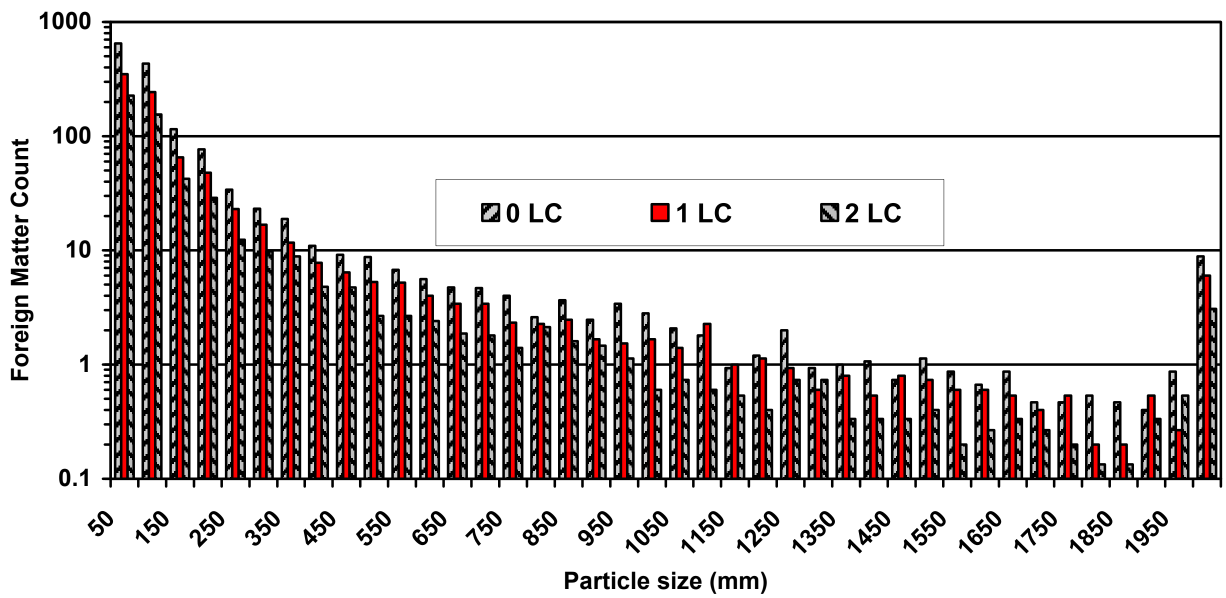


Figure 4. Particle size distribution, based on particle count, for a selected gin: before lint cleaning (0 LC), after the 1st saw-type lint cleaner (1 LC), and after the 2nd lint cleaner (2LC). Note – the scale of the Y-axis is logarithmic.

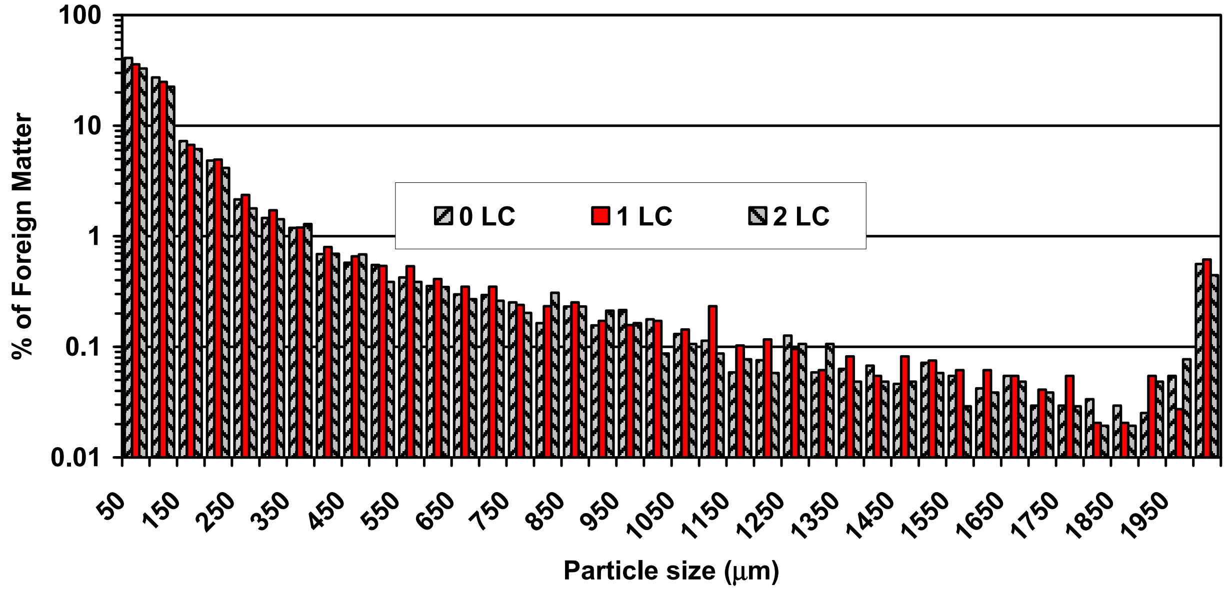


Figure 5. Particle size distribution, based on percentage of total count, for a selected gin: before lint cleaning (0 LC), after the 1st saw-type lint cleaner (1 LC), and after the 2nd lint cleaner (2LC). Note – the scale of the Y-axis is logarithmic.

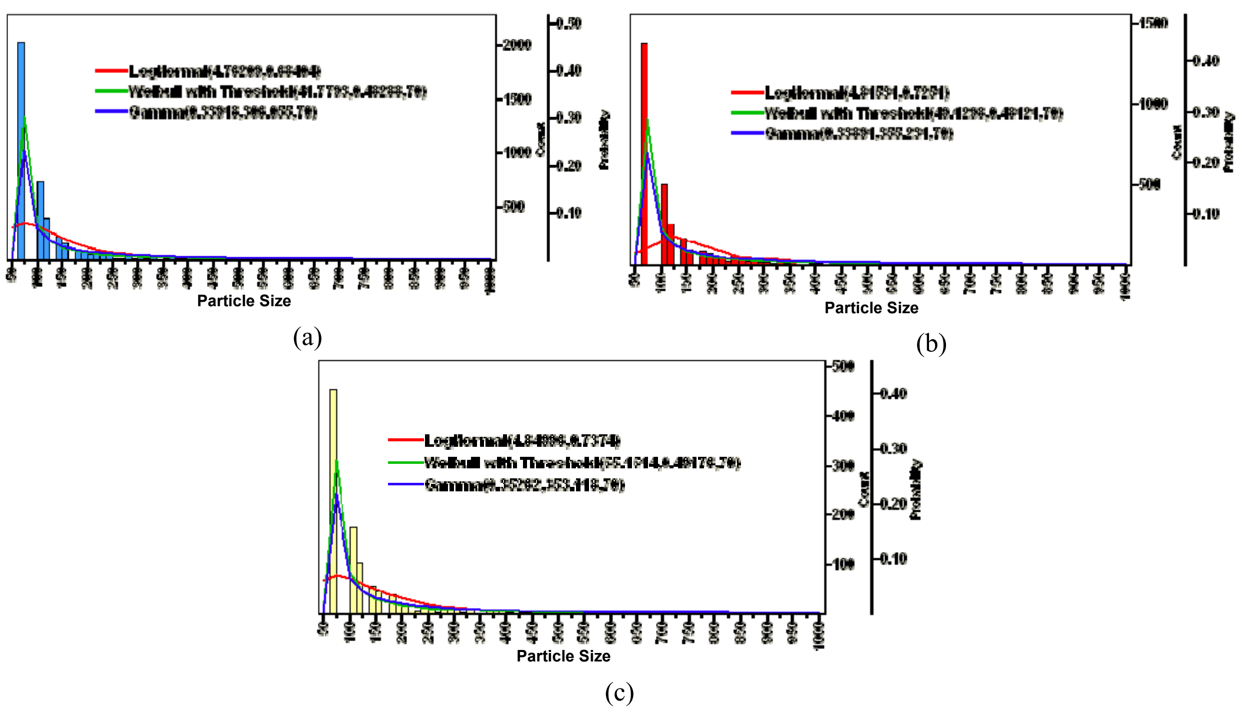


Figure 6. Probability density functions fit to foreign matter particle size distributions for cotton lint collected (a) before lint cleaning, (b) after 1st lint cleaner, and (c) after 2nd lint cleaner.

Disclaimer

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