PRESENTATION

Session:
GINNING NEWS

Title:
Lint Cleaning of Upland Cotton Using a Pneumatic Fractionator

Speaker:
Jaya Shankar Tumuluru, USDA-ARS, Southwestern Cotton Ginning Research Laboratory, Las Creces, New Mexico (USA)

Conference Organisation
Faserinstitut Bremen e.V., Bremen, Germany. E-Mail: conference@faserinstitut.de
Bremer Baumwollboerse, Bremen, Germany. E-Mail: info@baumwollboerse.de

Lint Cleaning of Upland Cotton Using a Pneumatic Fractionator

Jaya Shankar Tumuluru[1], Carlos Armijo[1], Derek Whitelock[1], Christopher D Delhom[2], Paul Funk[1], and Neha Kothari[3]

[1]USDA-ARS, Las Cruces, NM, USA

[2]USDA, ARS, Leland, MS, USA

[3]Cotton Incorporated, Cary, NC, USA

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Introduction

- Lint cleaning removes the foreign matter from ginned lint.
- Novel lint cleaning systems such as the pneumatic fractionator are needed to remove foreign matter and preserve lint quality.

Current state of art

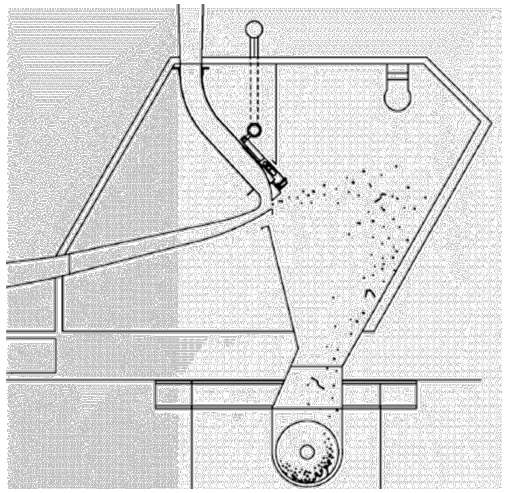
In commercial cotton ginning plants, saw-type (saw gin) or pin-type (roller gin) lint cleaners are used.

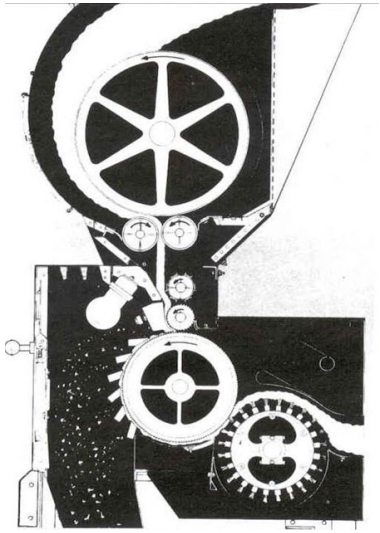
Saw-type lint cleaner:

- ✓ aggressive at removing foreign material
- ✓ reduces the fiber length and length uniformity
- ✓ increases short fiber content and neps

Pin-type lint cleaner:

- ✓ less aggressive at removing foreign matter
- ✓ less damaging to the fiber

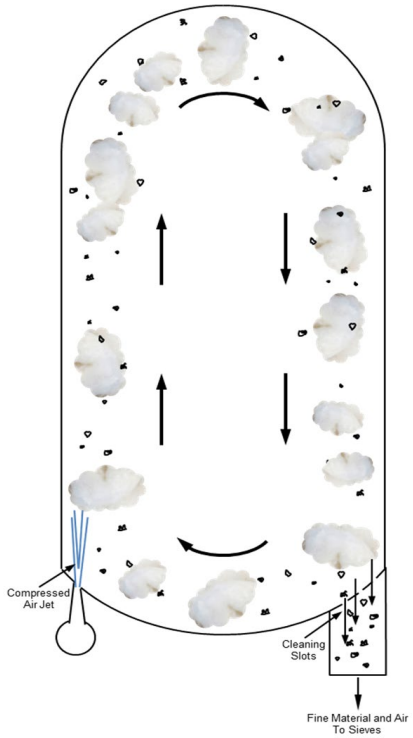




Earlier work on Pneumatic fractionator

- Pneumatic fractionator "effectively removes the foreign matter and does not damage the lint quality"
- Previous work did not examine:
  - Interaction effect of lint moisture with a) line pressure and b) residence time,
  - Modeling and optimization of the pneumatic fractionator
  - Comparing lint quality with conventional lint cleaning system (saw and pin type) used by the industry

Fractionator working principle



Fractionator at the SW Cotton Ginning Lab, Las Cruces, NM, USA

Objectives of this research

- Determine the impact of the pneumatic fractionator (FRAC) process conditions lint moisture, residence time and line pressure on final lint moisture, trash content and HVI properties.

- Model and optimize the FRAC process for saw and roller ginned Upland cotton

- Compare saw and roller gin Upland cotton lint quality with respect to:
  - No lint cleaning (NO LC) (immediately after ginning)
  - After saw- and pin-type lint cleaning (1-LC) (Industry Standard)
  - At the optimized FRAC process conditions

Cotton variety

NexGen 4545 Upland cotton that was picker harvested

Fractionation process conditions

- Lint moisture content (MC) : 5.3-15 % (w.b.)
- Line pressure (LP): 40-80 (psig)
- Residence time (RT): 15-45 (sec)

Experiments were conducted based on central composite design

Product quality

- **Fractionation process properties**
  - ✓ Lint moisture content
  - ✓ Total trash (motes+ leaf + fine trash)
- **HVI properties**: Micronaire, upper half mean length, uniformity index, trash count, strength, reflectance, yellowness and short fiber content.

Methods

Moisture addition:

- Amount of moisture added to lint samples was based on the initial moisture content.
- The treated lint samples were stored in sealed polyethylene bags overnight in a refrigerator set at 4°C to allow for moisture equilibration.
- 20 grams of the sample was used for moisture measurement and 50 grams was used for the fractionation test.

Lint Moisture measurement

Oven drying about 20 grams of lint for about 2 hours at 105°C.

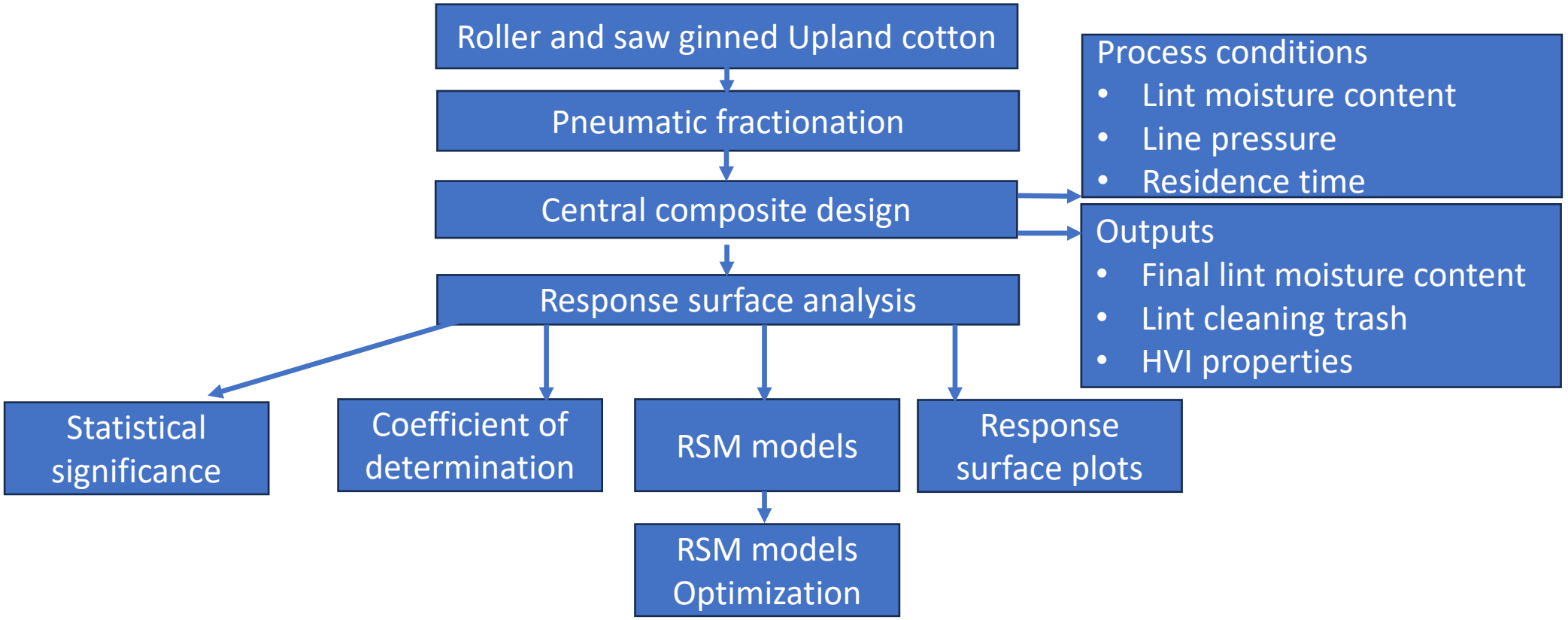
Lint cleaning trash

Lint trash (motes, leaf & fine trash) was collected on No. 6 (3.35 mm) and No. 200 (75 microns) sieves associated with the pneumatic fractionator.

Lint properties

High Volume Instrument (HVI) determined the lint properties after no lint cleaning (NO LC), after Industry Standard lint cleaning (1-LC) and after fractionation (FRAC).

Data analysis



RSM model developed for roller and saw ginned fractionated samples

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum \sum_{i<j} \beta_{ij} x_i x_j + \varepsilon$$

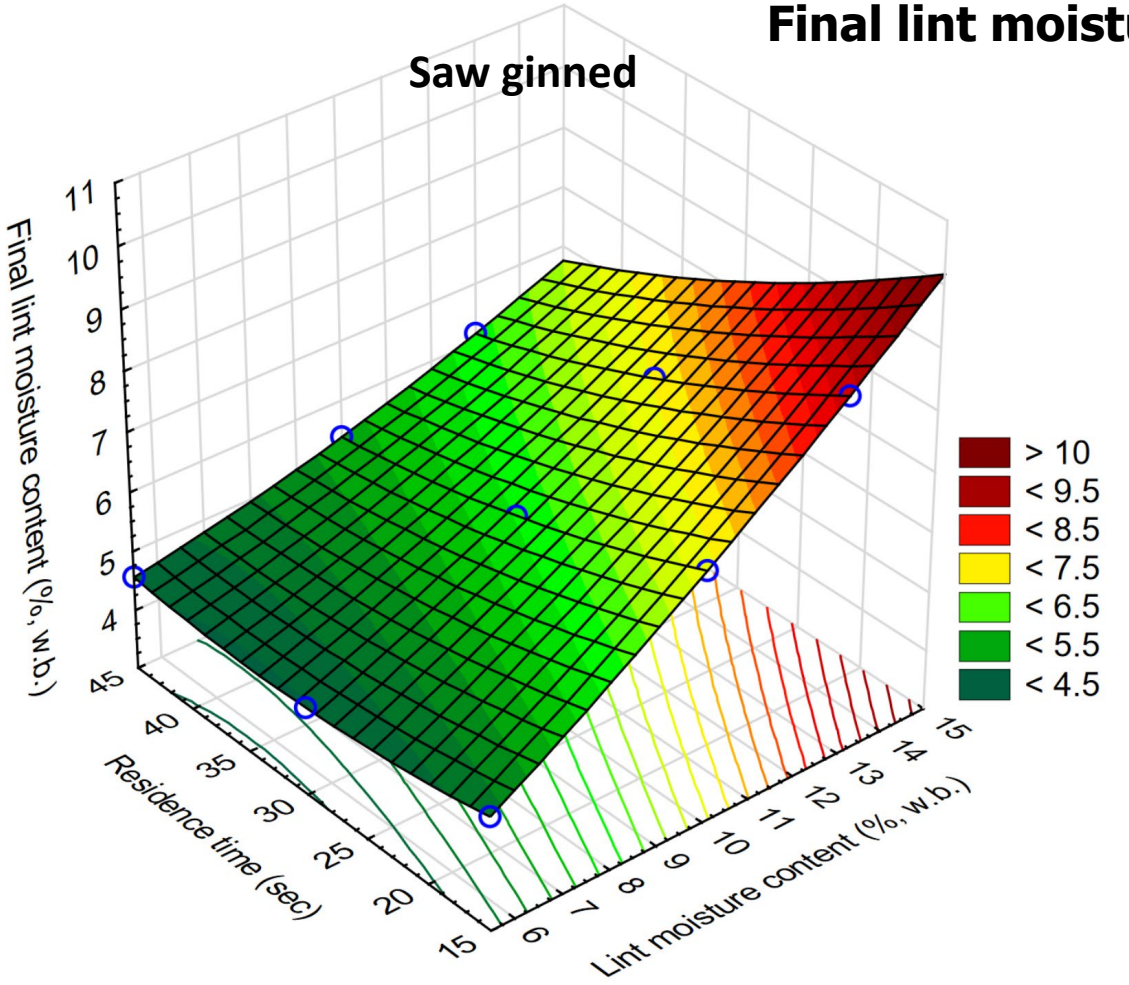
Results

	Saw ginned samples		Roller ginned samples	
Fractionator process models	**Model (R^2)**	**Statistically significant variables**	**Model (R^2)**	**Statistically significant variables**
Final moisture content (%, w.b.)	0.99	• Lint moisture content • Residence time	0.95	• Lint moisture content • Residence time
Total trash	0.99	• Lint moisture content • Line pressure • Residence time	0.99	• Lint moisture content • Line pressure • Residence time
HVI property				
Upper half mean length (mm)	0.94	• Lint moisture content • Line pressure • Residence time	0.78	• Lint moisture content • Line pressure
Uniformity index (%)	0.80	None	0.88	• Line pressure
Trash count (number of particles per gram)	0.87	• Lint moisture content	0.96	• Lint moisture content • Line pressure • Residence time
Strength (grams/tex)	0.81	None	0.60	• Line pressure
Short fiber content (%)	0.92	• Lint moisture content • Residence time	0.89	Residence time
Spinning consistency index	0.83	None	0.80	Line pressure
Reflectance (Rd)	0.77	• Line pressure	0.59	None
Yellowness (+b)	0.83	• Line pressure	0.69	• Lint moisture content • Line pressure
Micronaire	0.88	• Lint moisture content • Residence time	0.46	None

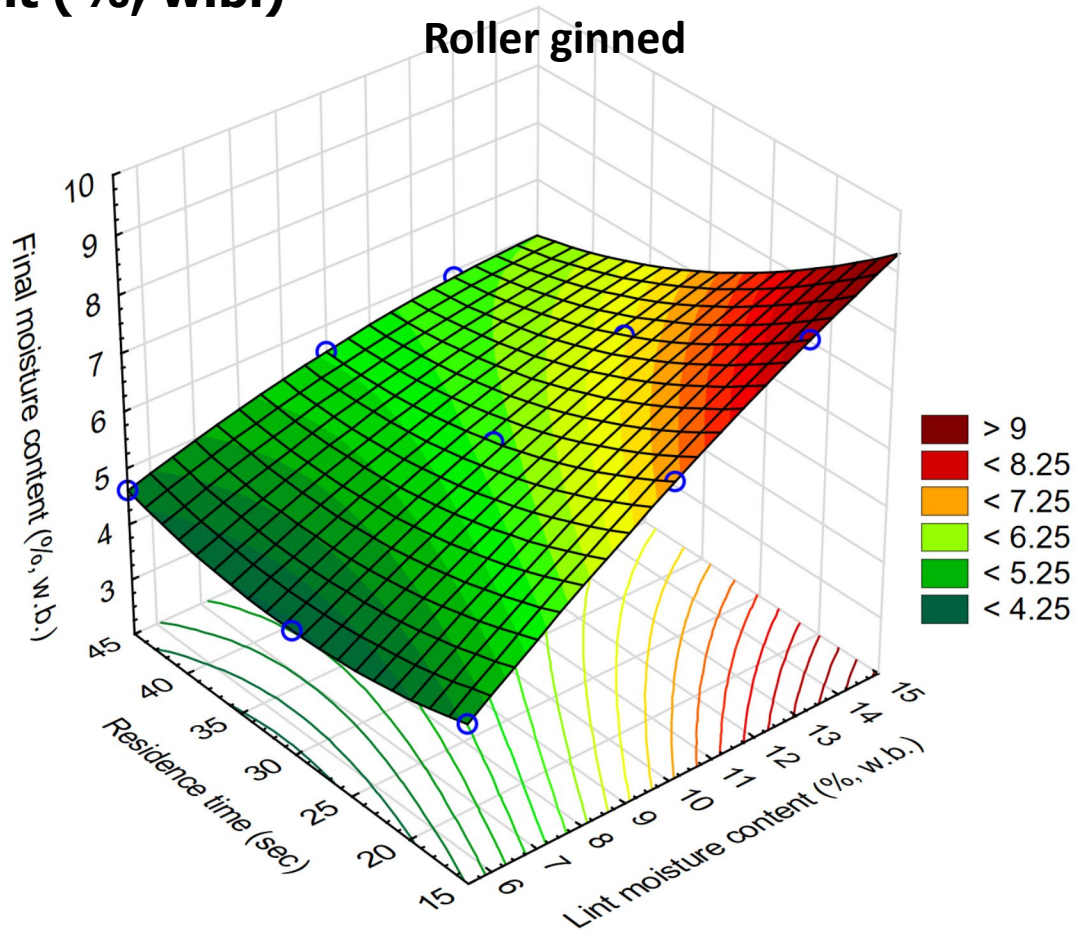
Examples of the Some RSM based Surface plots

Final lint moisture content (%, w.b.)

Saw ginned



Roller ginned

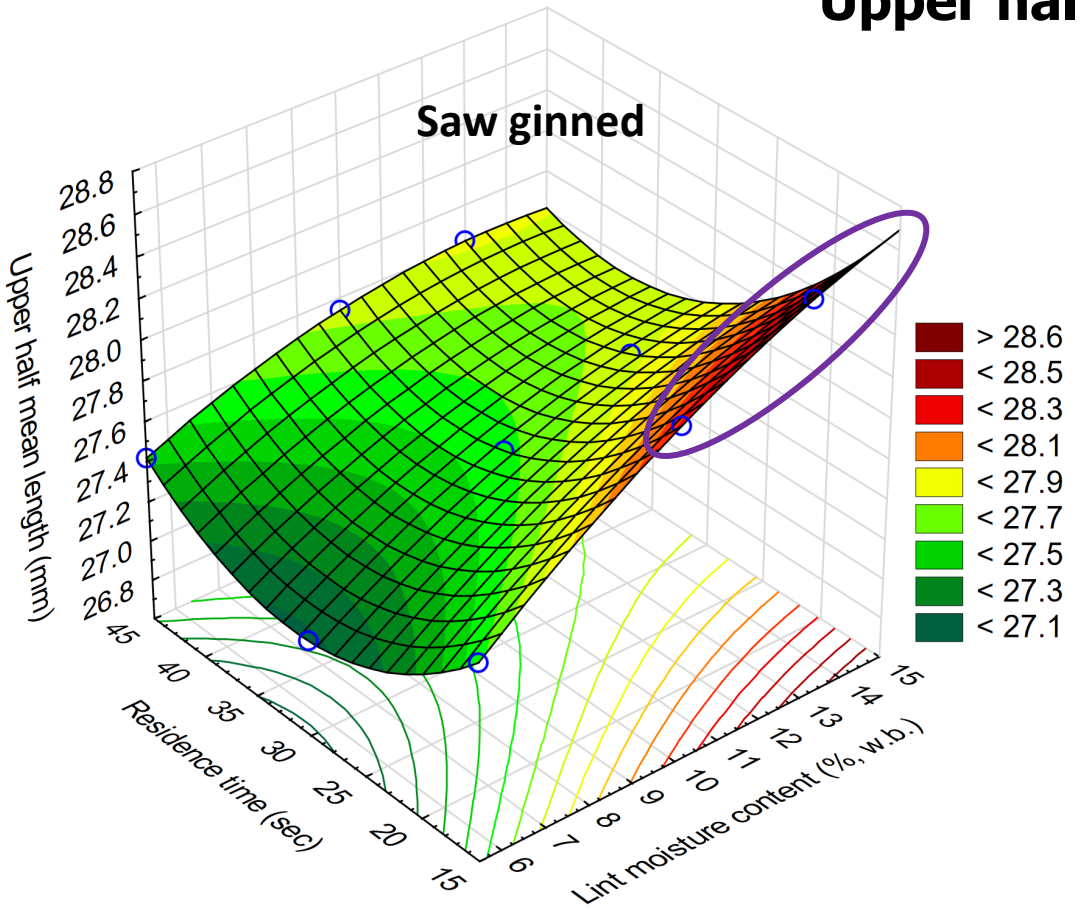


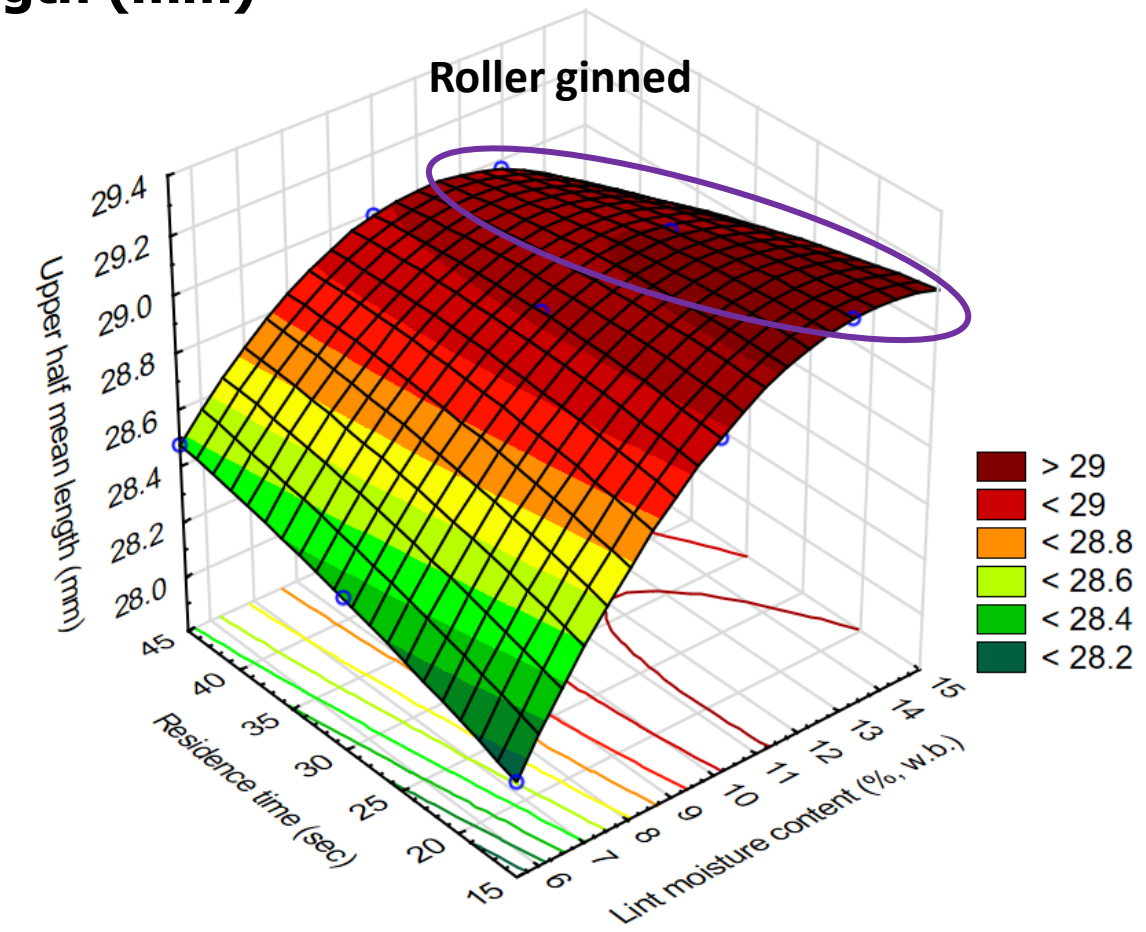
Initial Lint MC has a big impact on the final lint MC for both saw and roller ginned FRAC lint

At Higher lint MCs, higher LP or higher RT, lint MC reduced significantly

50 % reduction in the lint MC when RT and LP is >30 sec, >60 psig

Upper half mean length (mm)



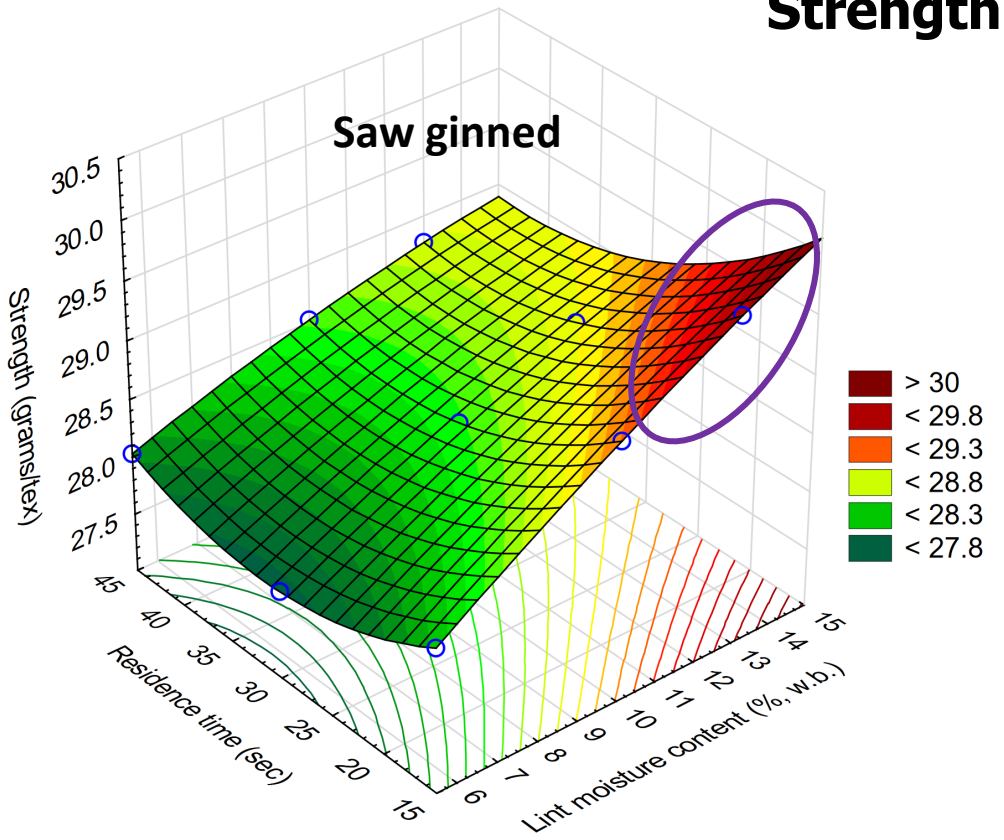


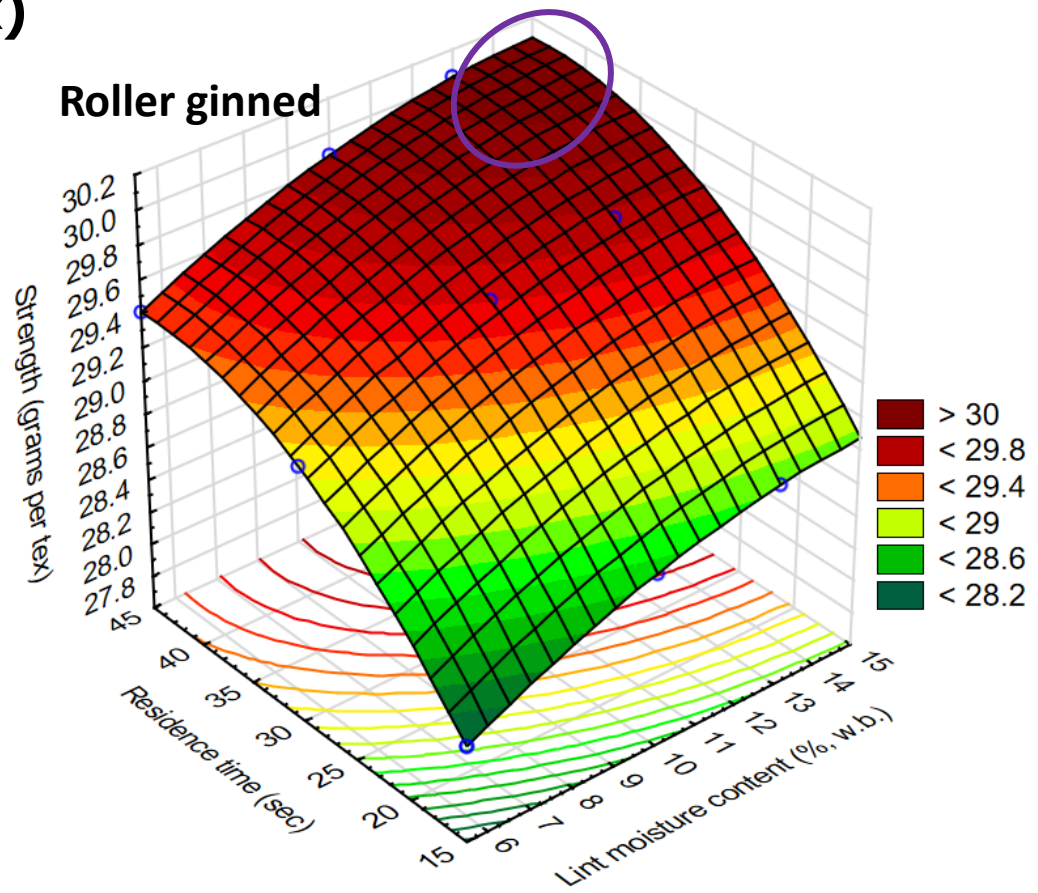
- UHML >28.6 mm (1.12 inch), observed at higher lint MC > 12 % and lower RT of <20 sec
- UHML <27.4 mm (1.07 inch) was observed at lower lint MC of 5.5% and all RTs

UHML increased to >29 mm (1.14 inch) at >12 % lint MC and RT had marginal effect.

Roller ginned upland cotton is less sensitive to RT during FRAC at higher lint MCs

Strength (grams/tex)



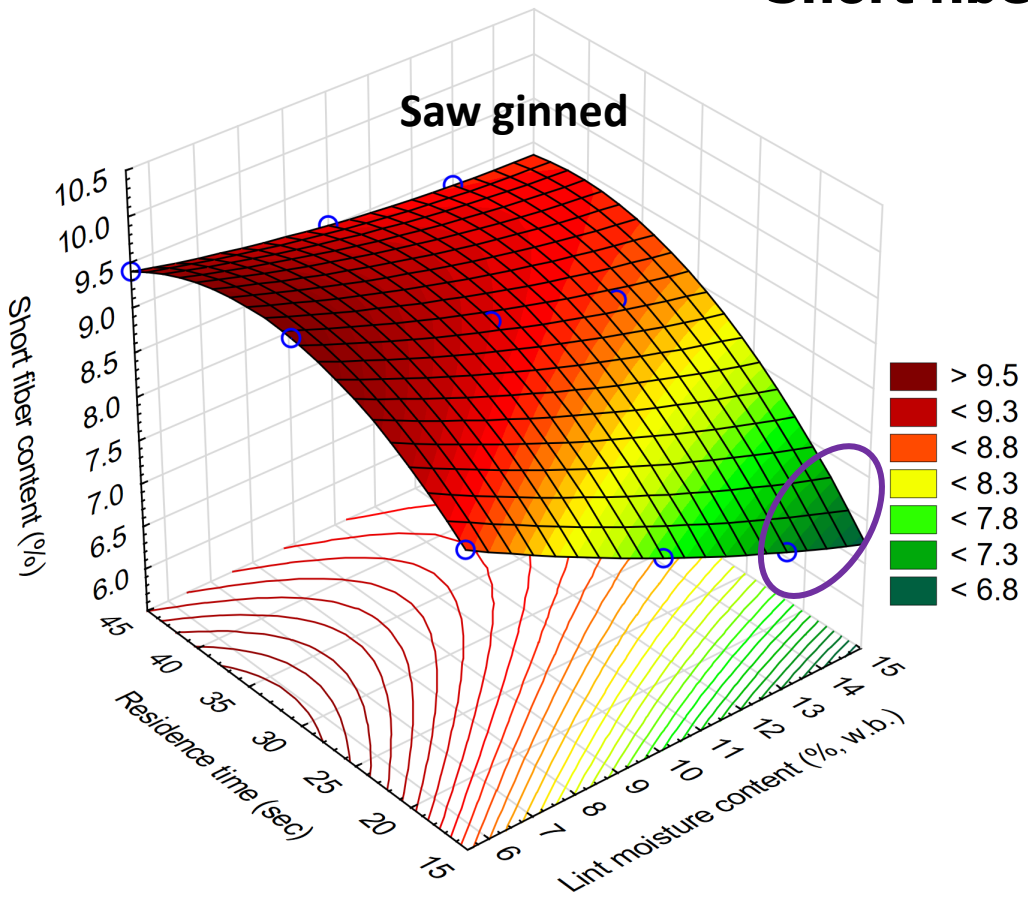


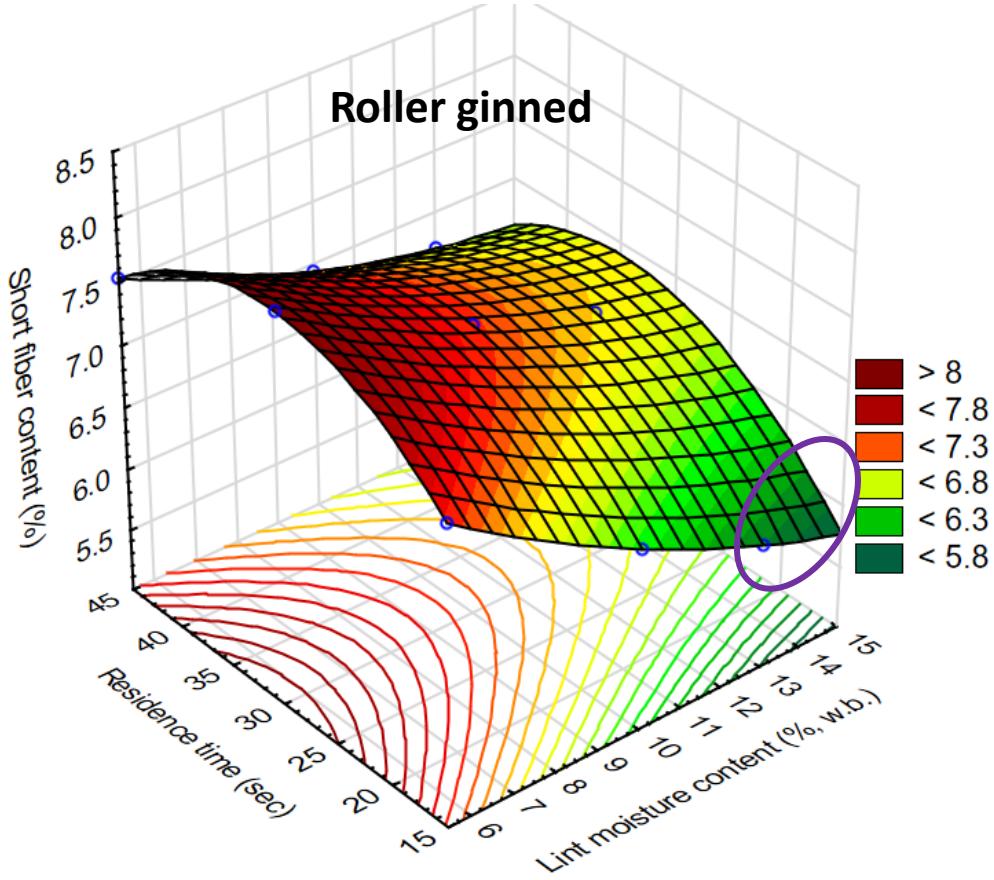
- Strength >30 grams/tex at higher lint MC and lower RT
- Strength <27.8 grams/tex at lower MC of 5.5% at all the RTs.

Strength >30 grams/tex ,at higher lint MC and medium to higher RTs

Trends of the lint MCs are same for both saw, and roller ginned FRAC lint, but not the residence time

Short fiber content (%)



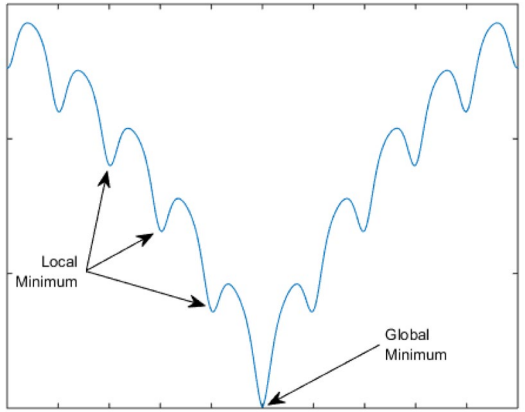


Higher SFCs was observed in saw ginned compared to roller ginned FRAC samples

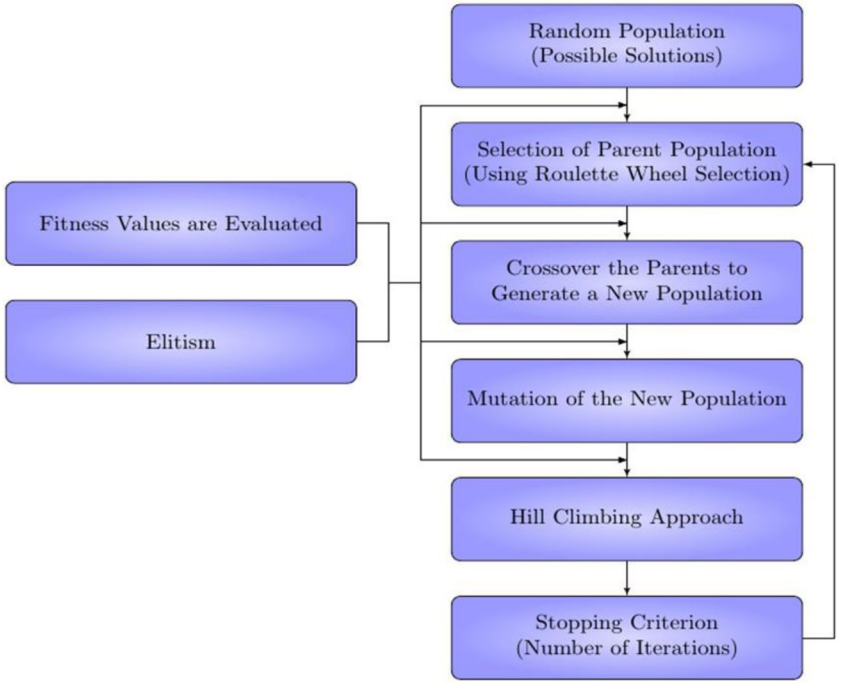
Trends of the SFC are similar for both saw and roller ginned FRAC lint

Higher lint MCs and lower RTs reduced the SFC

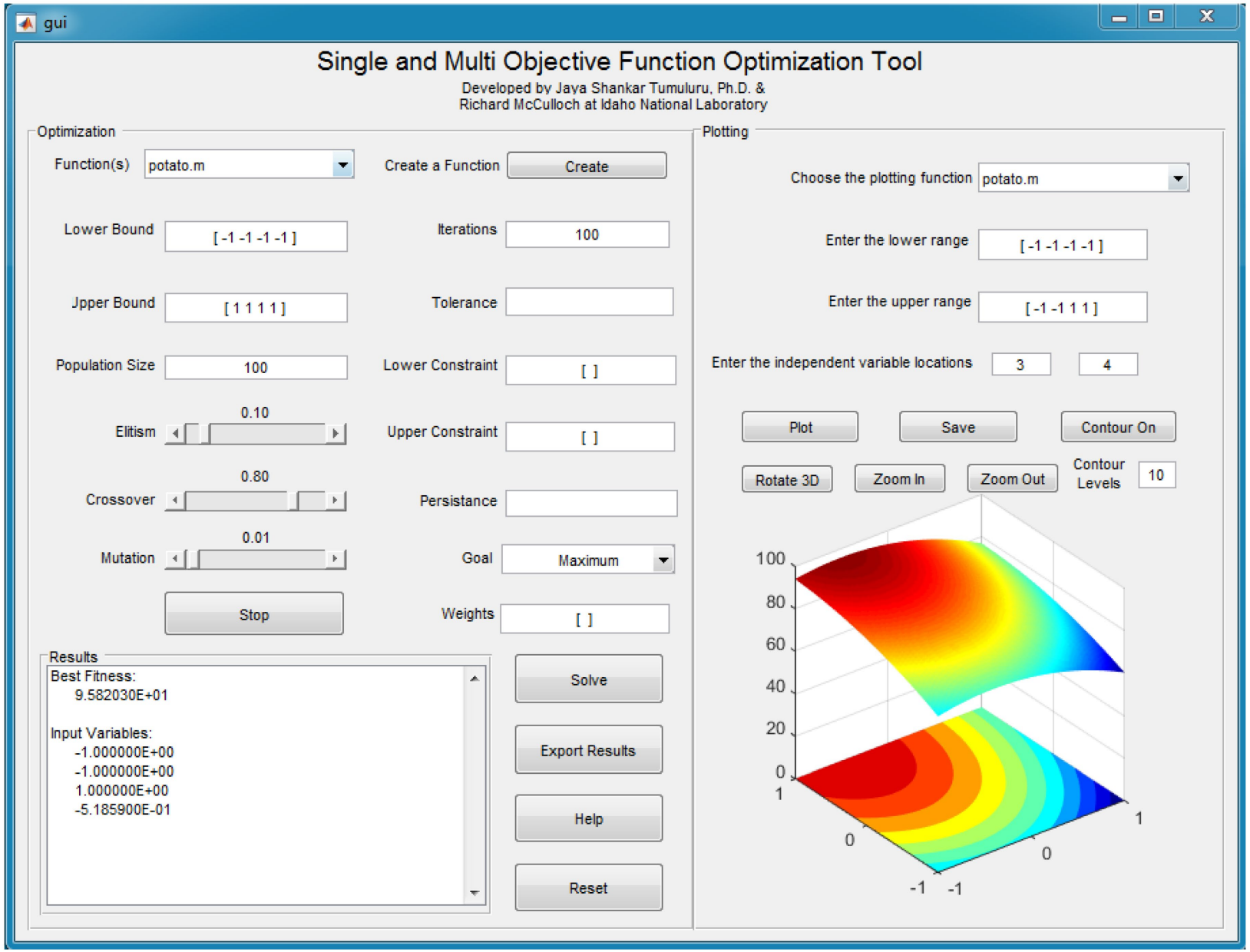
Optimization of the models



Local and global optimum points in function minimization



Flow diagram of the hybrid genetic algorithm (HGA)



User front-end of the Multi-Objective Optimization Tool (Tumuluru and McCulloch, 2016)

Optimization criteria for roller and saw ginned FRAC samples

Maximize

1. Upper half mean length (UHML)
2. Uniformity index (UI)
3. Strength (STR)
4. Reflectance (RD)
5. Yellowness (+b)
6. Spinning consistency index (SCI)
7. Lint cleaning trash (LCT)

Minimize

1. Final lint moisture (FLM)
2. Micronaire (MIC)
3. Short fiber content (SFC)
4. Trash count (Trash cnt)

Objective function developed for optimziation of lint properties

$$f(y) = Maximize((UHML + UI + STR + RD + (+b) + SCI + LCT) - (FLM + MIC + SFC + Trash\ cnt))$$

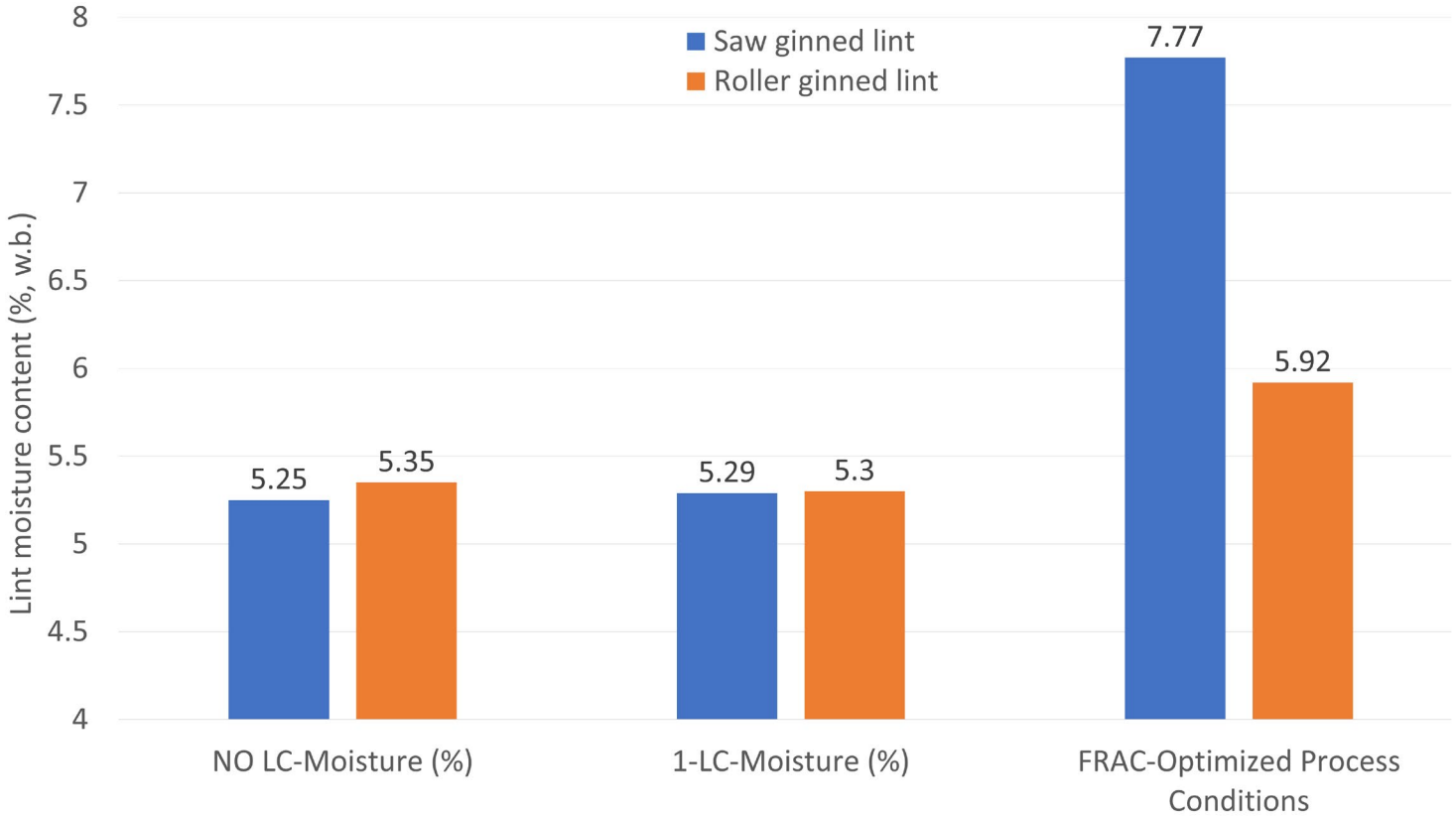
Fractionator Optimized Process Conditions

Optimized FRAC Process conditions	Roller ginned FRAC lint	Saw ginned FRAC lint
Lint moisture content (%, w.b.)	13.3	14.9
Line pressure (psig)	79.8	79.9
Residence time (sec)	36.67	15.1

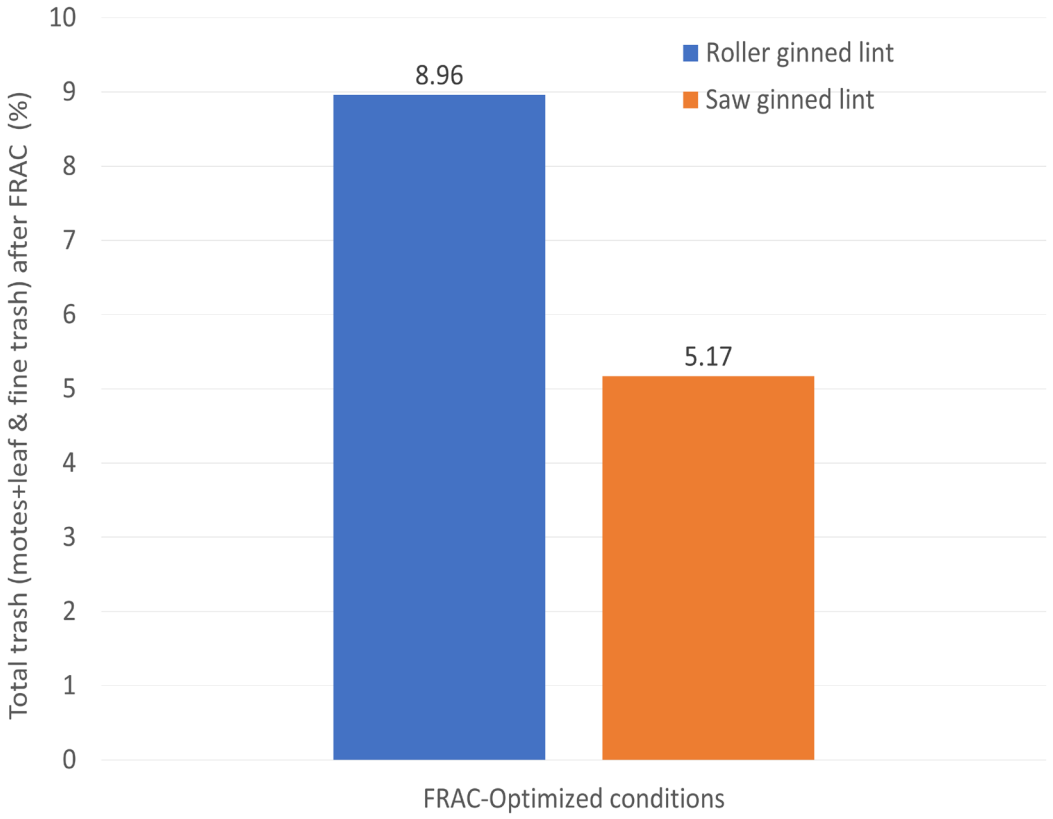
Residence time was the interacting variable influencing the HVI properties of roller and saw ginned FRAC lint.

Comparison of properties NO LC, 1-LC and FRAC at optimized conditions

Lint moisture content & total trash



No Linting Cleaning **Industry Standard (1-LC)** **FRAC**

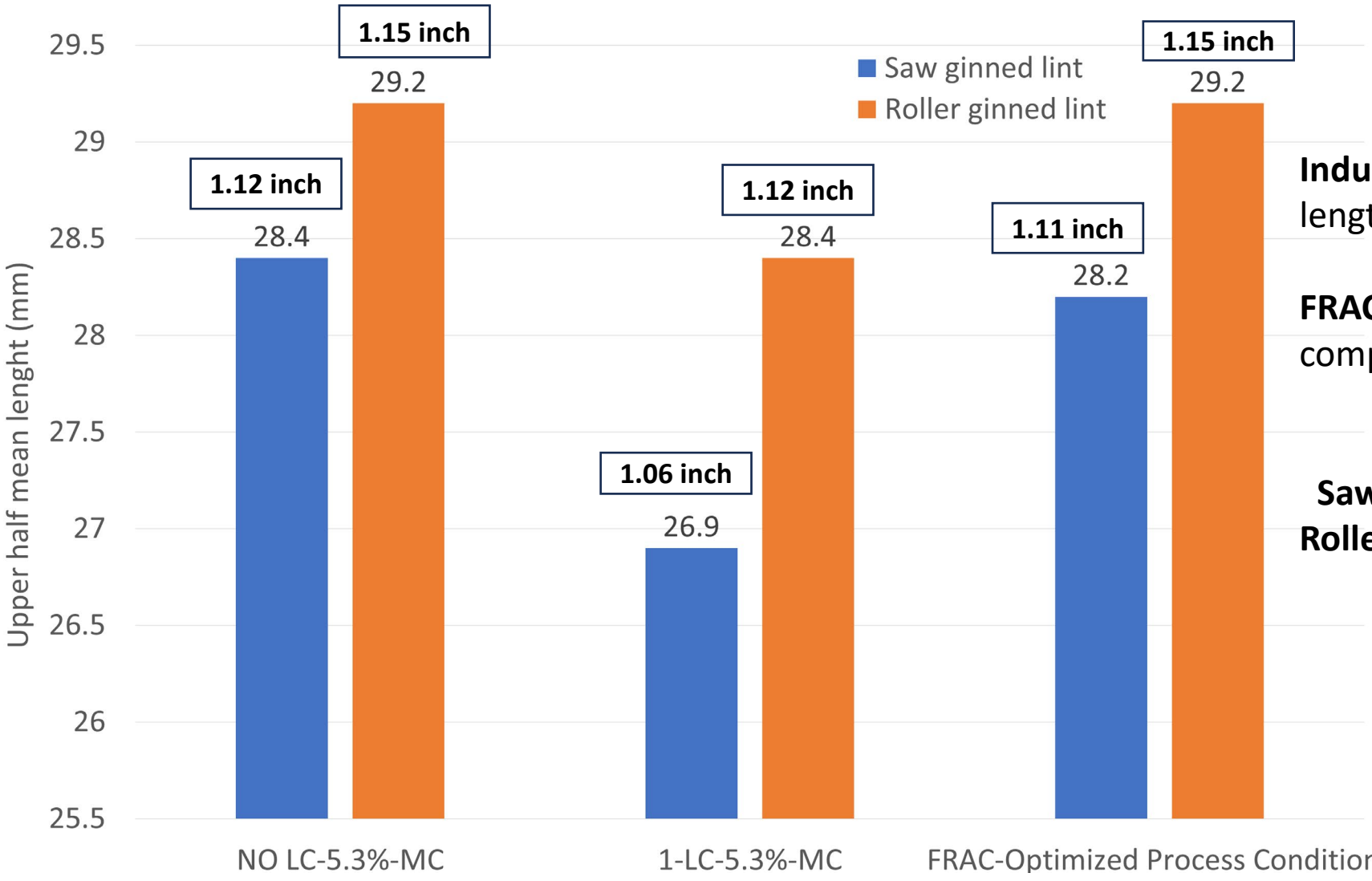


73% increase in total trash removal when RT is increased from 15 sec (saw) to 36 sec (roller).

- Industry Standard 1-LC: No moisture change in lint for both and saw for roller ginned lint.
- FRAC: 48 and 56 % decrease in MC for saw and roller ginned samples.

HVI properties

Upper half mean length (mm)

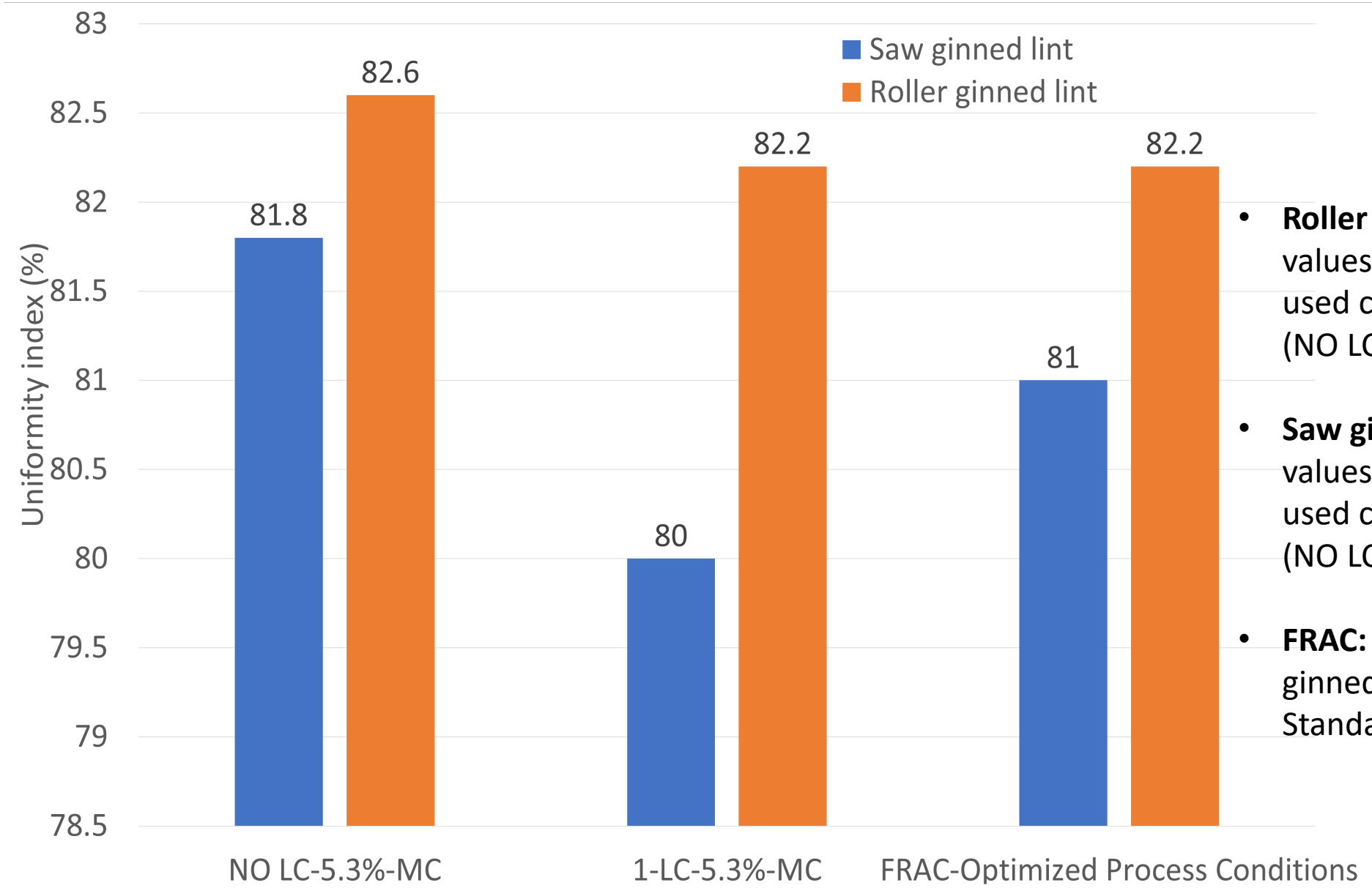


Industry Standard 1-LC: Reduced the staple length of both roller and saw ginned lint.

FRAC: No reduction in staple length compared to No Lint Cleaning (NO LC).

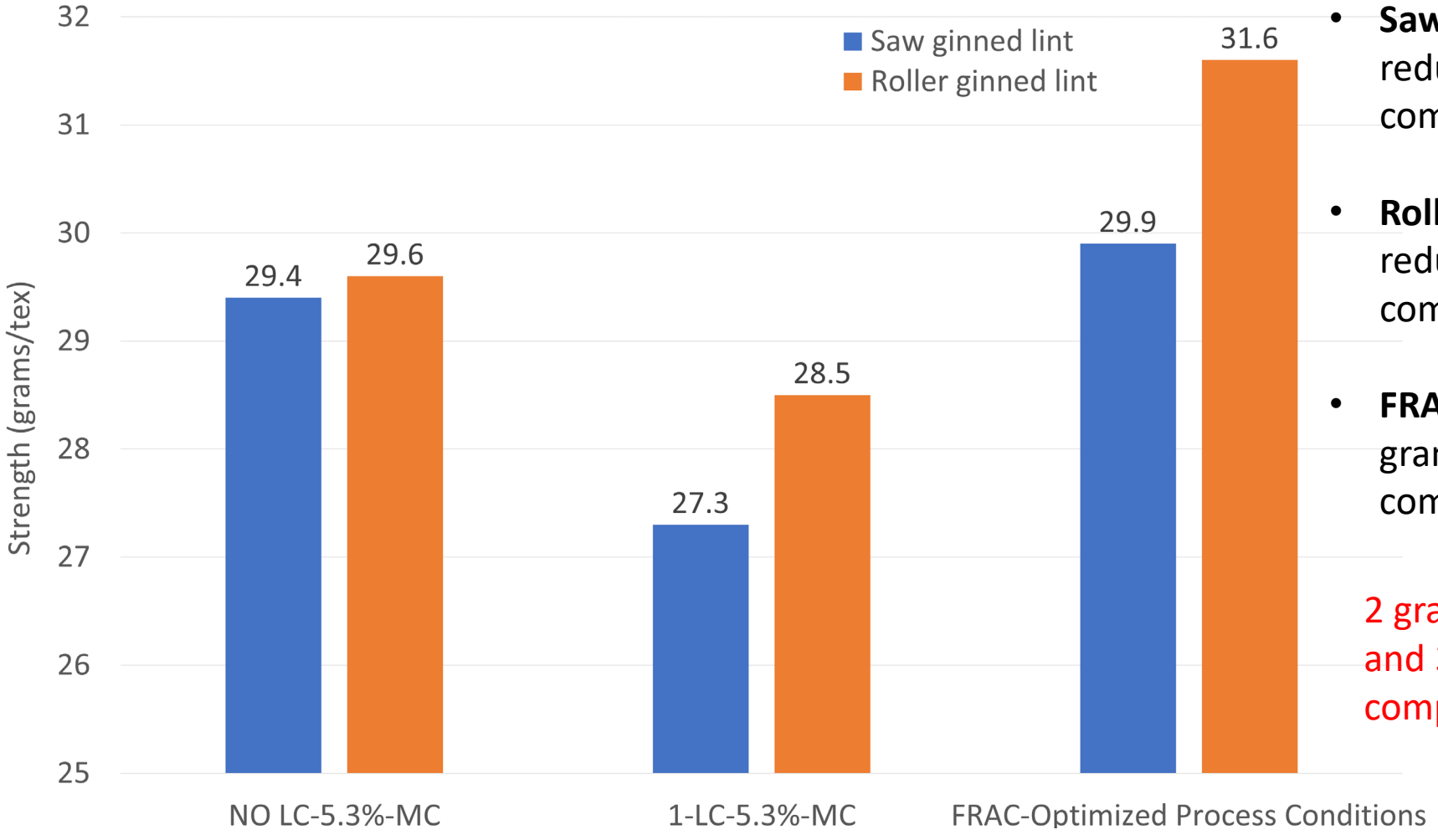
	NO LC	1-LC	FRAC
Saw gin	36	34	36
Roller gin	37	36	37

Uniformity index (%)



- **Roller ginned lint**:0.5 % decrease in UI values when Industry Standard 1-LC is used compared to No Lint Cleaning (NO LC).
- **Saw ginned lint:** 1.8 % decrease in UI values when Industry Standard 1-LC is used compared to No Lint Cleaning (NO LC).
- **FRAC:** 1 % increase in UI values for saw ginned FRAC compared to Industry Standard 1-LC .

Strength (grams/tex)



- **Saw ginned lint:** Industry Standard 1-LC reduces the strength by 2 grams/tex compared to No Lint Cleaning (NO LC)
- **Roller ginned lint:** Industry Standard 1-LC reduced the strength by 1 gram/tex compared to No Lint Cleaning (NO LC).
- **FRAC:** Increase the strength by 2.0 and 0.5 grams/tex for roller and saw ginned lint compared to No Lint Cleaning (NO LC).

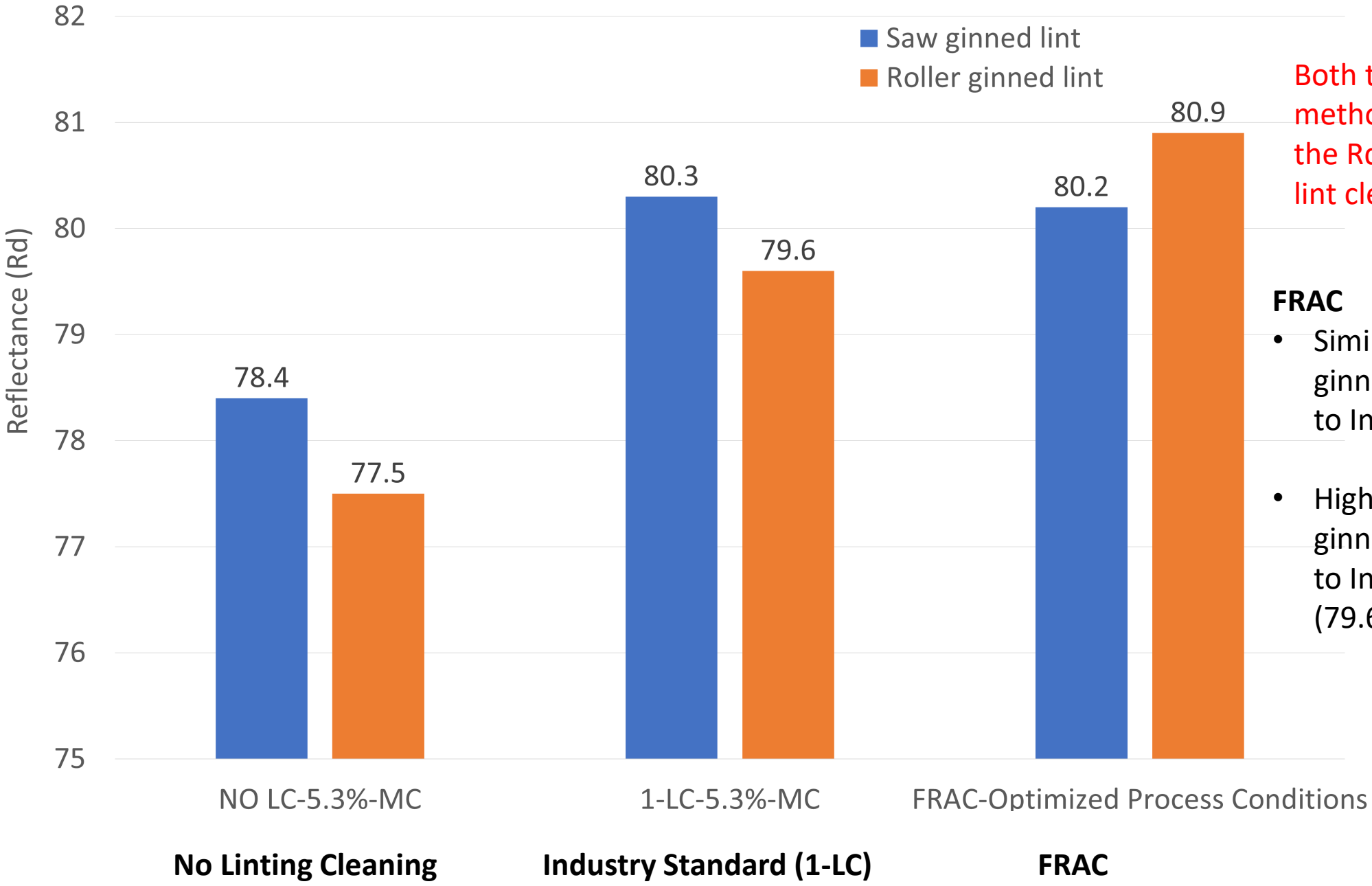
2 grams/tex higher strength of saw ginned and 3 grams/tex for roller ginned FRAC lint compared to Industry Standard 1-LC

No Linting Cleaning **Industry Standard (1-LC)** **FRAC**

Higher lint MC during FRAC had a positive impact for both saw and roller ginned lint

	NO LC	1-LC	FRAC
Saw ginned	Strong	Average	Strong
Roller ginned	Strong	Strong	Very Strong

Reflectance (Rd)

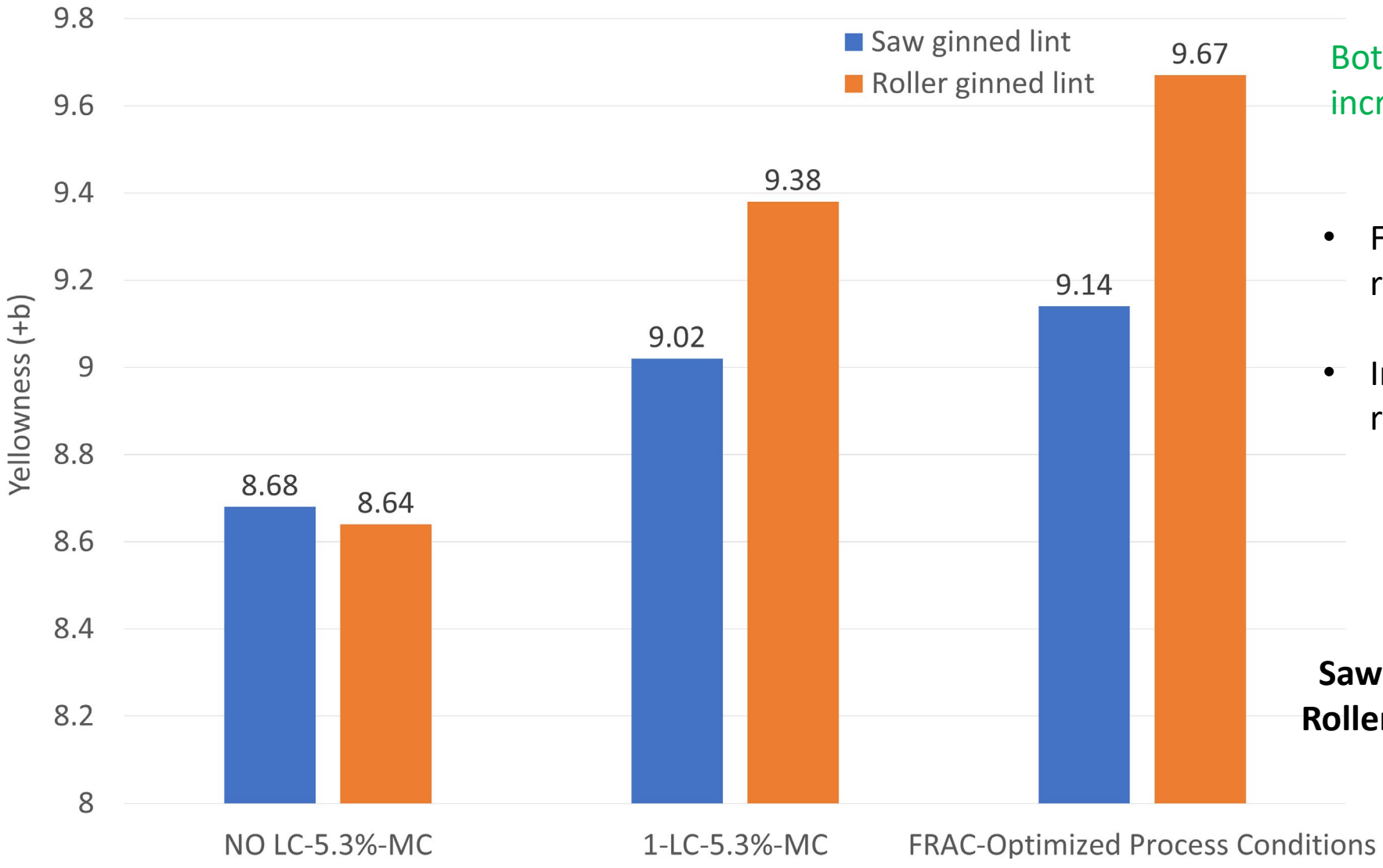


Both the lint cleaning methods positively impacted the Rd values compared to no lint cleaning

FRAC

- Similar Rd values for saw ginned FRAC lint compared to Industry Standard 1-LC.
- Higher Rd values for roller ginned FRAC lint compared to Industry Standard 1-LC (79.6 versus 80.8)

Yellowness (+b)



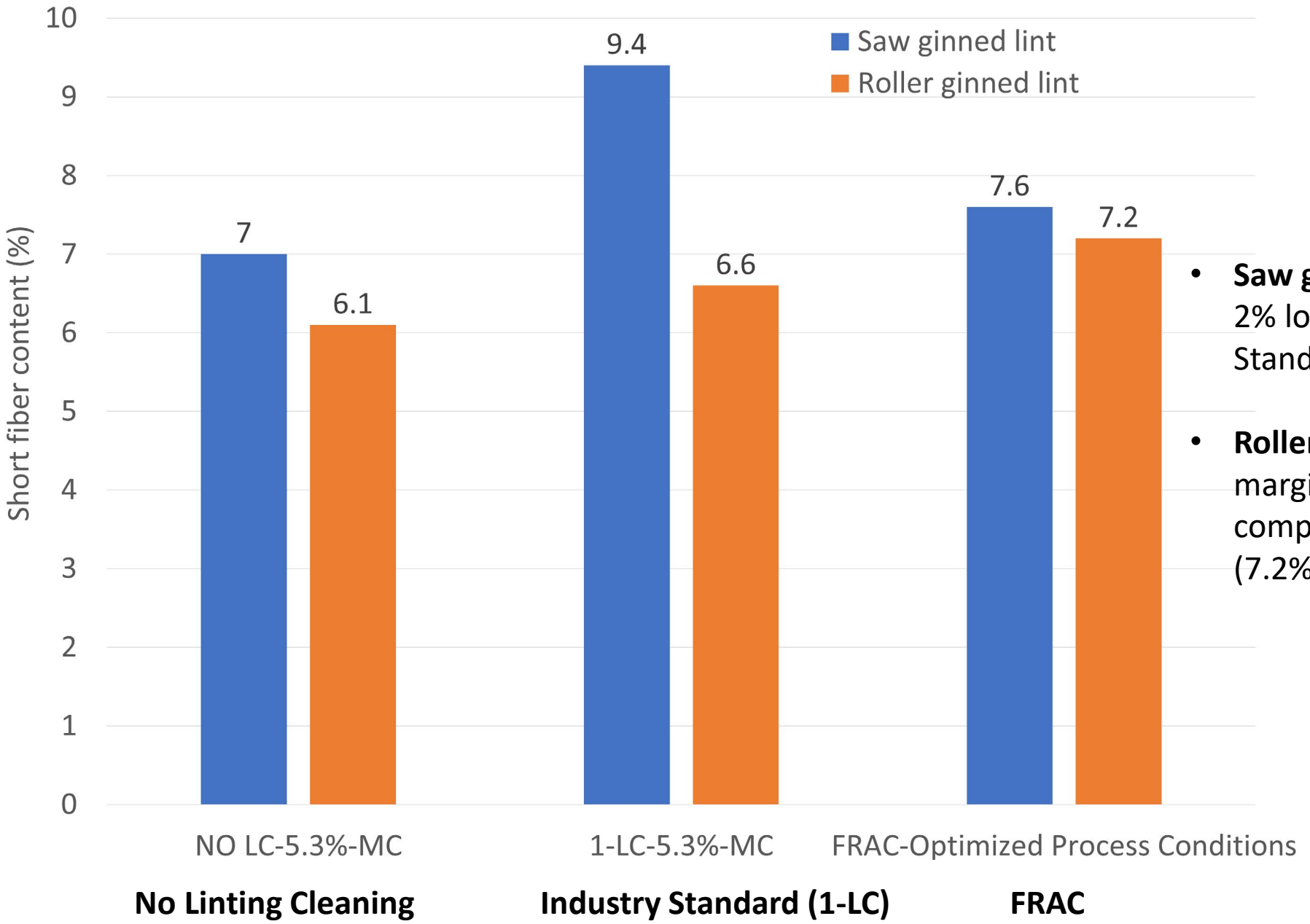
No Linting Cleaning **Industry Standard (1-LC)** **FRAC**

Both the lint cleaning methods increased the +b values

- FRAC of saw and roller ginned lint resulted in higher +b values.
- Impact of FRAC on +b values of roller ginned lint was higher.

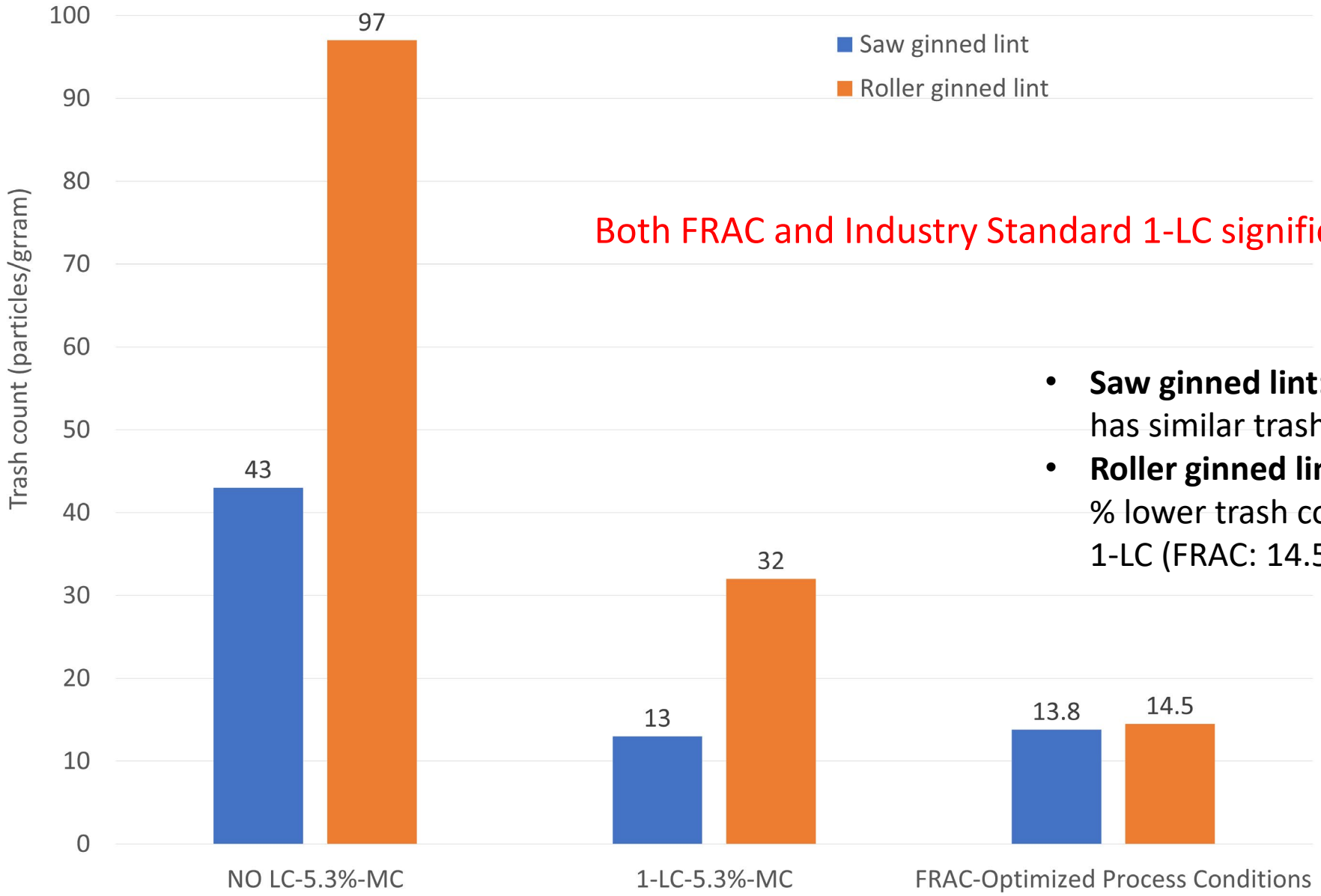
	NO LC	1-LC	FRAC
Saw ginned	31-1	21-2	21-1
Roller ginned	31-1	11-2	11-1

Short fiber content(%)



- **Saw ginned lint:** FRAC resulted about 2% lower SFC compared to Industry Standard 1-LC (9.4 versus 7.6).
- **Roller ginned lint:** FRAC resulted in marginal increase (0.6%) in SFC compared to Industry Standard 1-LC (7.2% versus 6.6%).

Trash count (particles/gram)

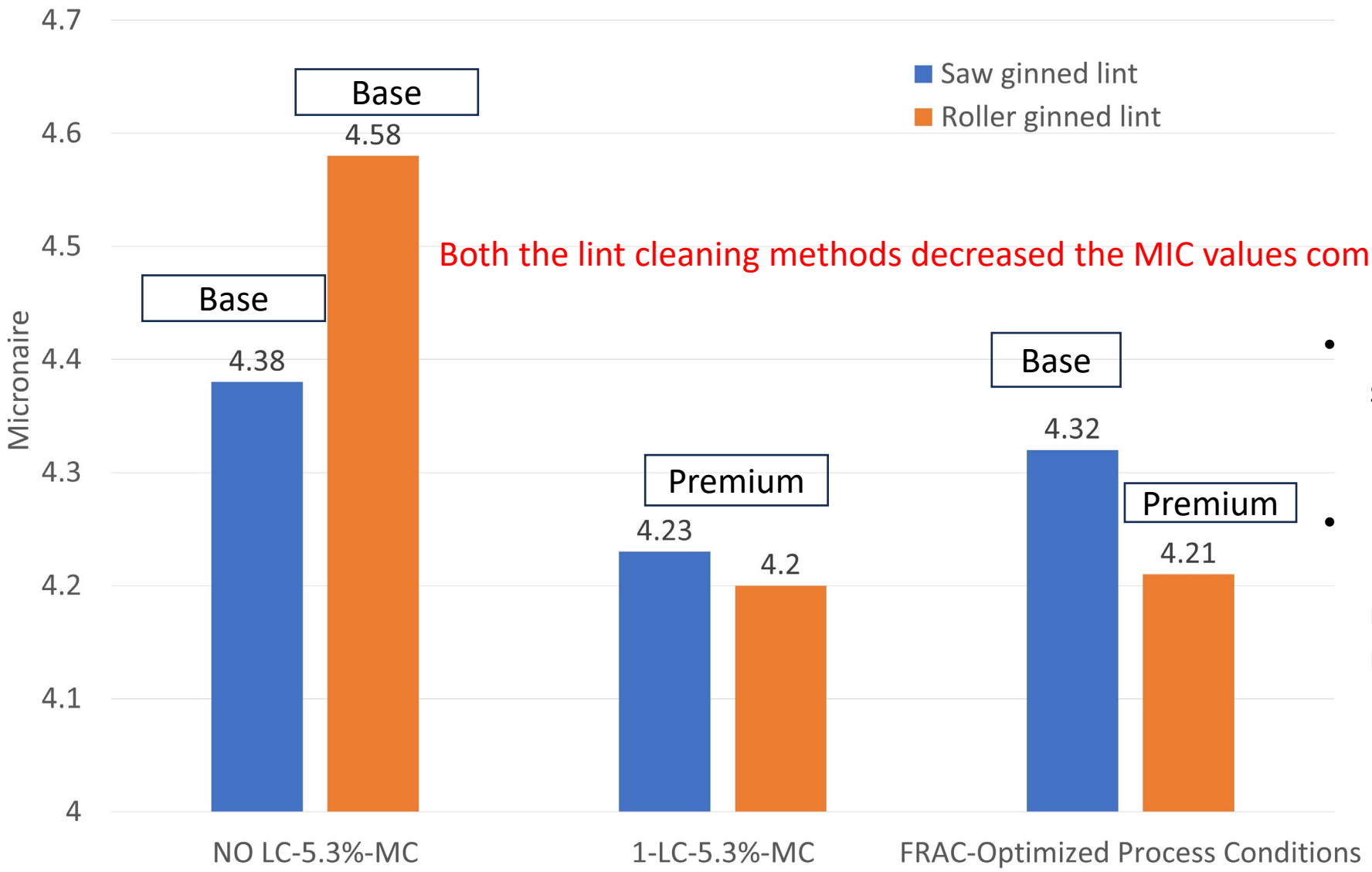


No Linting Cleaning **Industry Standard (1-LC)** **FRAC**

Both FRAC and Industry Standard 1-LC significantly reduced the trash count

- **Saw ginned lint:** Industry Standard 1-LC and FRAC has similar trash count values (about 13).
- **Roller ginned lint:** FRAC resulted in greater than 50 % lower trash count compared to Industry Standard 1-LC (FRAC: 14.5 versus 1-LC: 32).

Micronaire

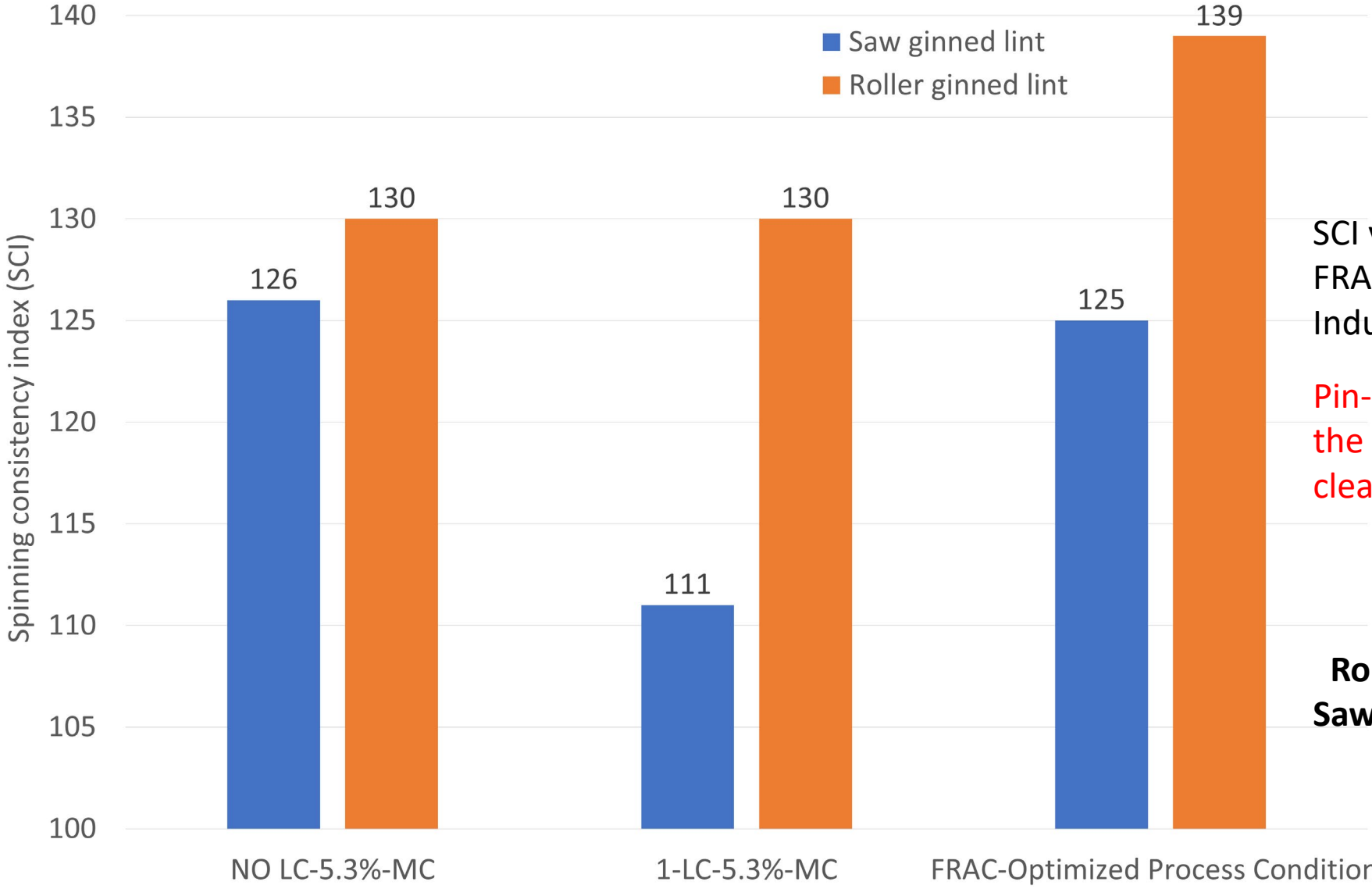


Both the lint cleaning methods decreased the MIC values compared to No Lint Cleaning (NO LC)

- Industry Standard 1-LC for both saw and roller ginned lint produced MIC in premium range.
- FRAC of saw ginned lint produced MIC in the Base range whereas roller ginned lint in the Premium range

No Linting Cleaning **Industry Standard (1-LC)** **FRAC**

Spinning consistency index (SCI)



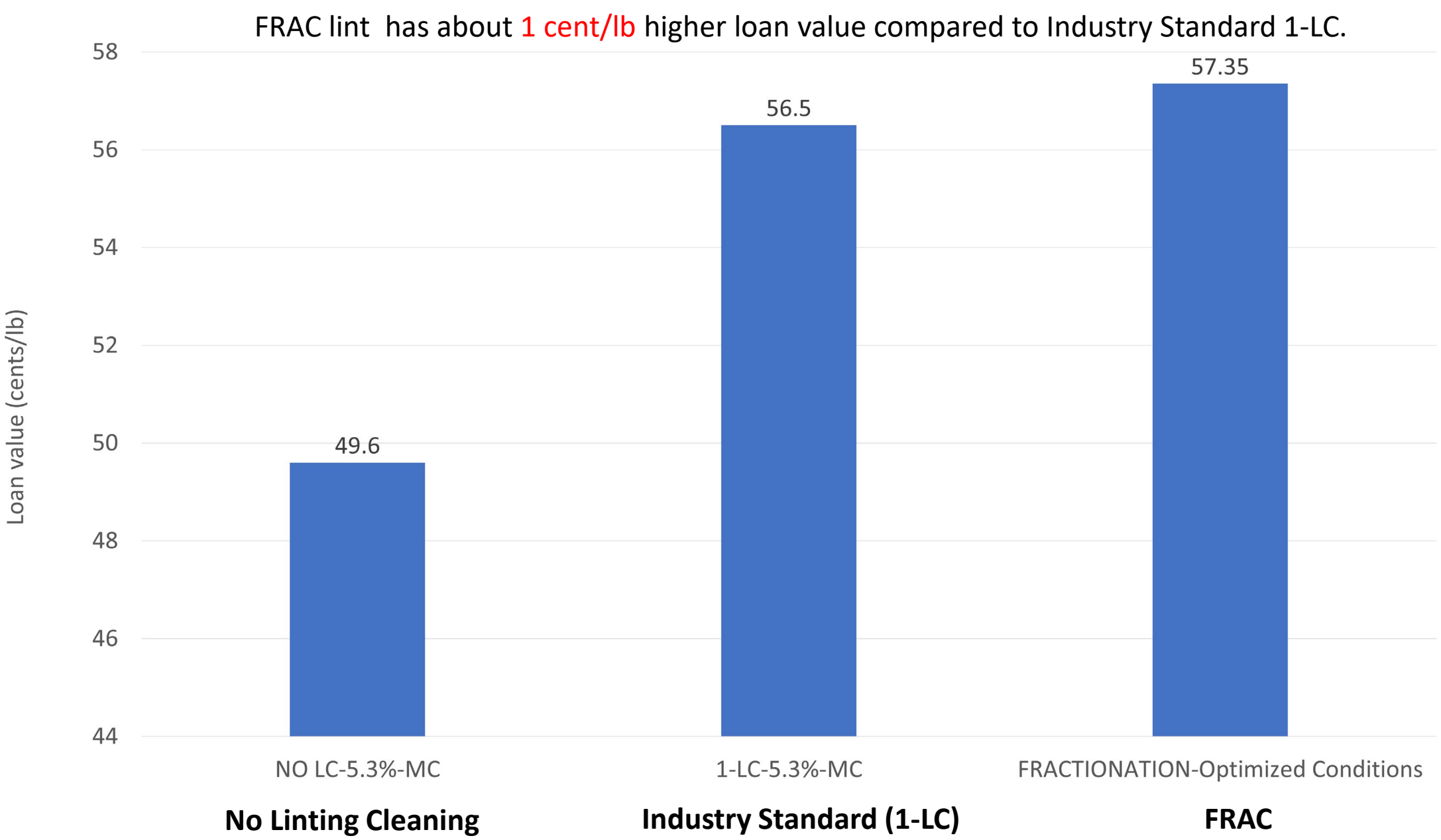
No Linting Cleaning **Industry Standard (1-LC)** **FRAC**

SCI values for both saw and roller ginned FRAC lint are higher compared to Industry Standard 1-LC

Pin-type lint cleaner had no impact on the SCI values, but the saw-type lint cleaner has a big impact.

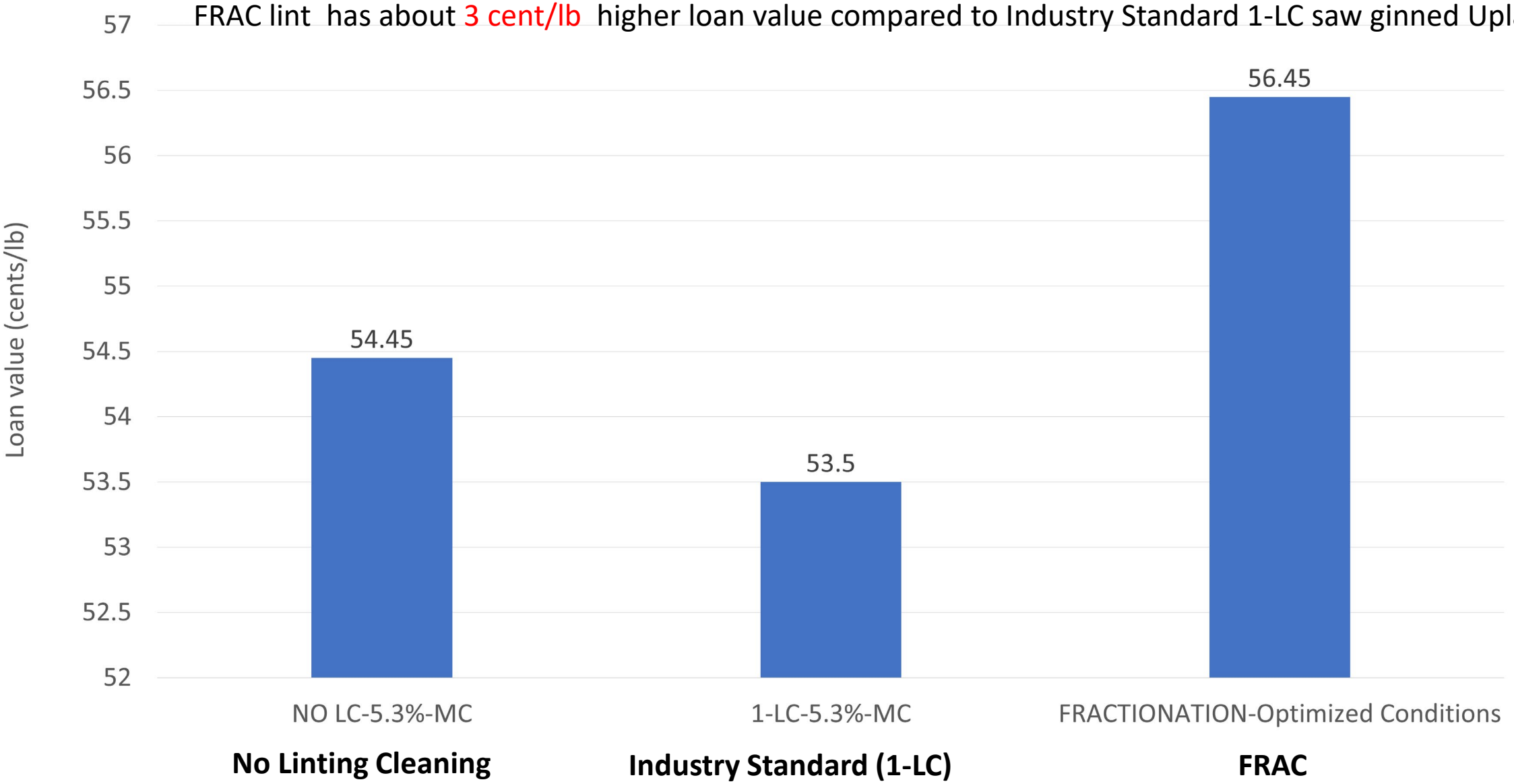
	NO LC	1-LC	FRAC
Roller ginned	130	130	139
Saw ginned	126	111	125

Loan value comparison for roller ginned NO LC, 1-LC and FRAC Upland cotton



Loan value comparison for saw ginned NO LC, 1-LC and FRAC Upland cotton

FRAC lint has about 3 cent/lb higher loan value compared to Industry Standard 1-LC saw ginned Upland cotton



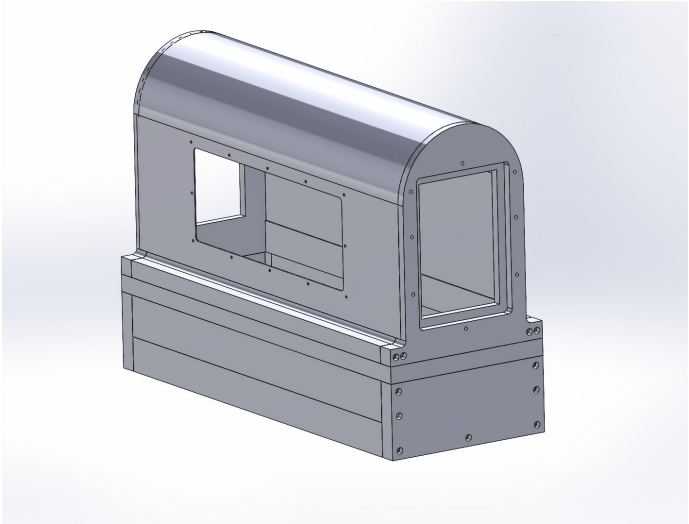
Conclusions

- Optimized process conditions are different for roller and saw ginned FRAC lint.
- Most of the HVI properties are positively impacted by FRAC.
- UHML and UI values are higher for FRAC compared to Industry Standard 1-LC.
- FRAC resulted in higher strength compared to No Lint Cleaning (NO LC) and Industry Standard 1-LC.
- Rd and +b values are higher for FRAC lint compared to Industry Standard 1-LC lint cleaning methods.
- FRAC resulted in about 50 % reduction in trash count compared to Industry Standard 1-LC for roller ginned lint
- Loan value for FRAC saw ginned lint is 3 cents/lb higher compared to Industry Standard 1-LC.

Future work

Developing a novel pneumatic lint cleaning system with the following features

— screens with different size, shapes and aspect ratios
— high-speed camera to understand the trash separation mechanism
— flowmeters and controls to allow an even air flow inside fractionator chamber
— modular to extend the length of the fractionator to scale-up



Lab scale novel pneumatic lint cleaning system

Acknowledgements

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