



Color elimination in white refined pan boiling crystallization

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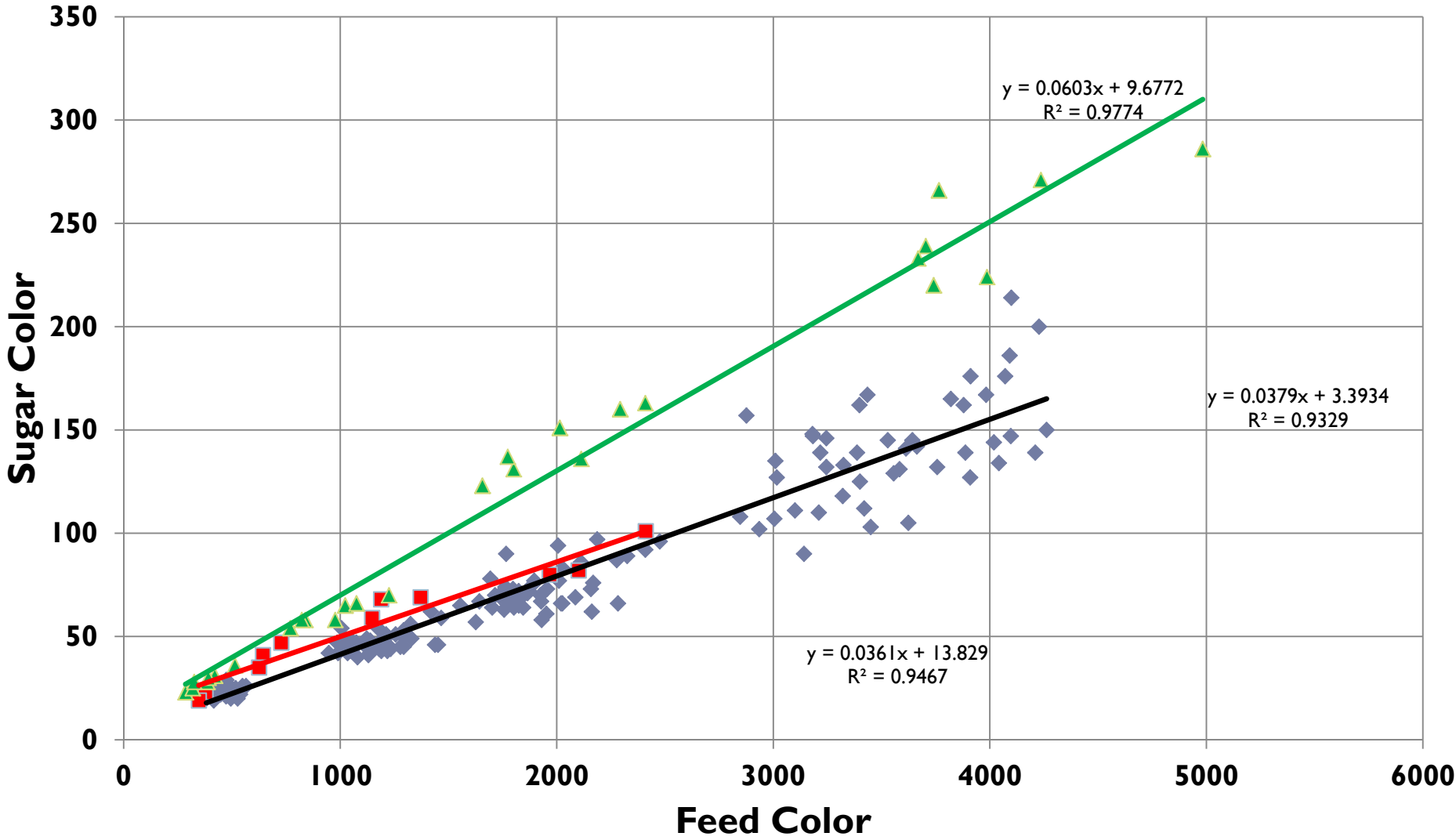
Introduction

- ▶ Crystallization is probably the most important operation in a refinery
- ▶ It has the biggest influence on energy efficiency.
- ▶ Crystallization is the most efficient form of color removal
- ▶ Why are there such big differences in color ratios (massecuite/sugar color, or feed/sugar color) reported in different places, and in the same place at different times?
- ▶ Can we identify reasons?
- ▶ Can we quantify the effects?
- ▶ What relationship should we use for prediction purposes?

Color inclusion in sugar crystals

- ▶ Color can be incorporated into the sugar in three ways:
 - ▶ By co-crystallizing with sucrose
 - ▶ By absorption on the crystal surface
 - ▶ By being trapped in a liquid inclusion in a conglomerate crystal
- ▶ The third mechanism is caused by poor control at seeding.
- ▶ Color on the surface of the crystal can be removed by affination or washing and it is color that co-crystallizes with sucrose which is the most important type of colorant.

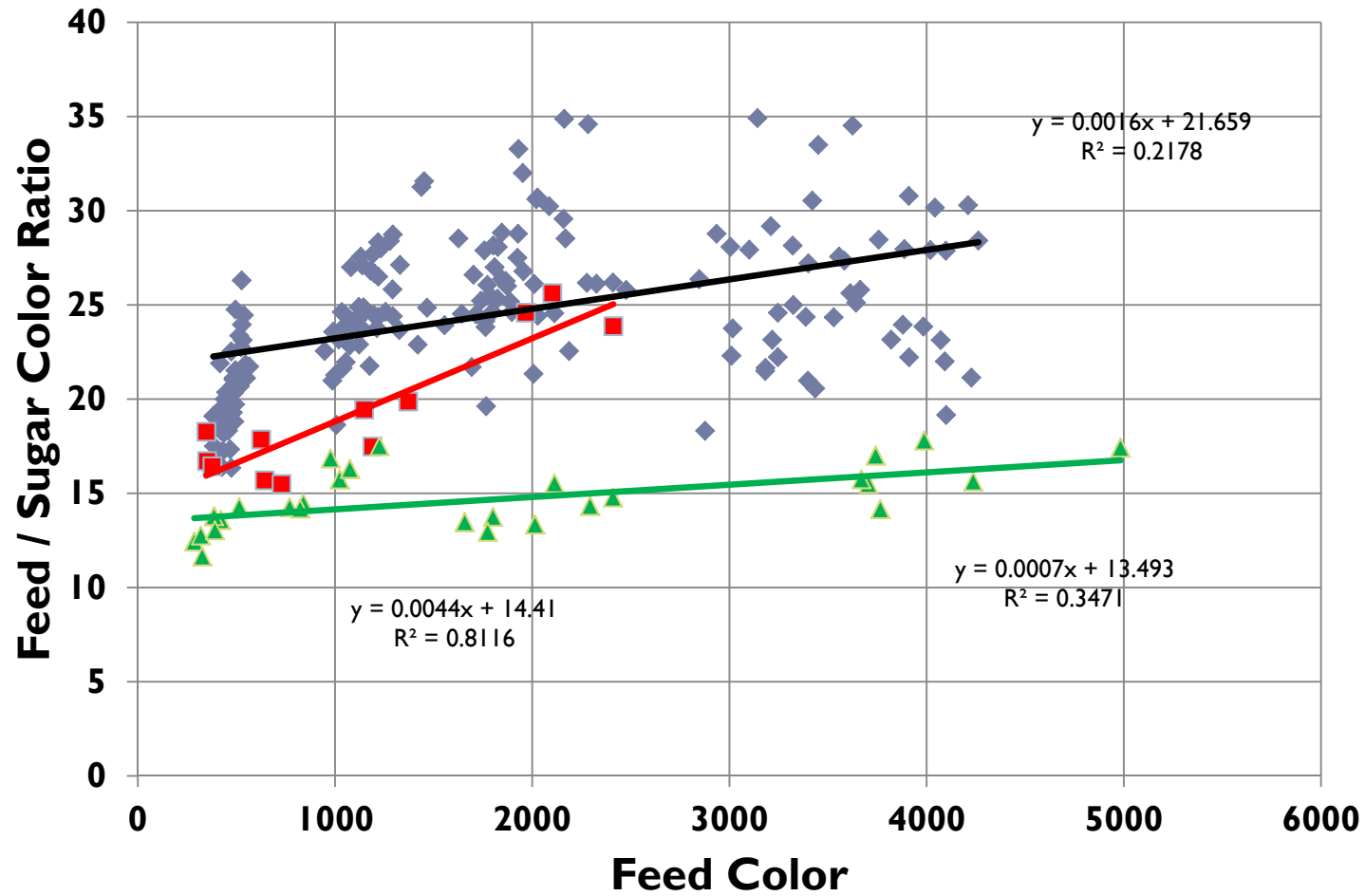
Hulett's Refinery Sugar Color vs. Feed Color



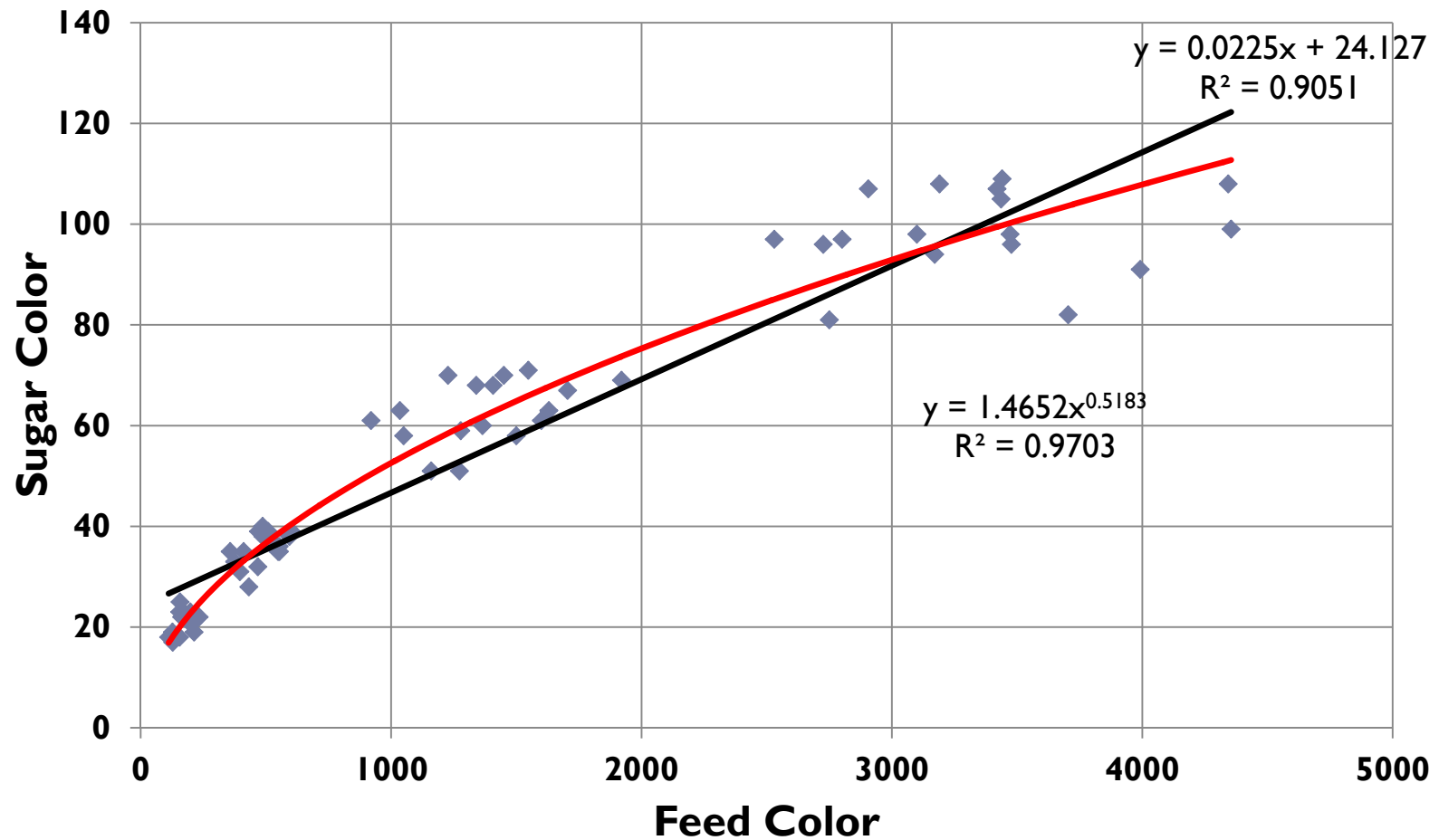
Terminology

- ▶ Use color ratio, i.e. feed/sugar color , or masecuite/sugar color.
- ▶ Color transfer is confusing – should it be high or low?
- ▶ Color elimination – what does it mean?

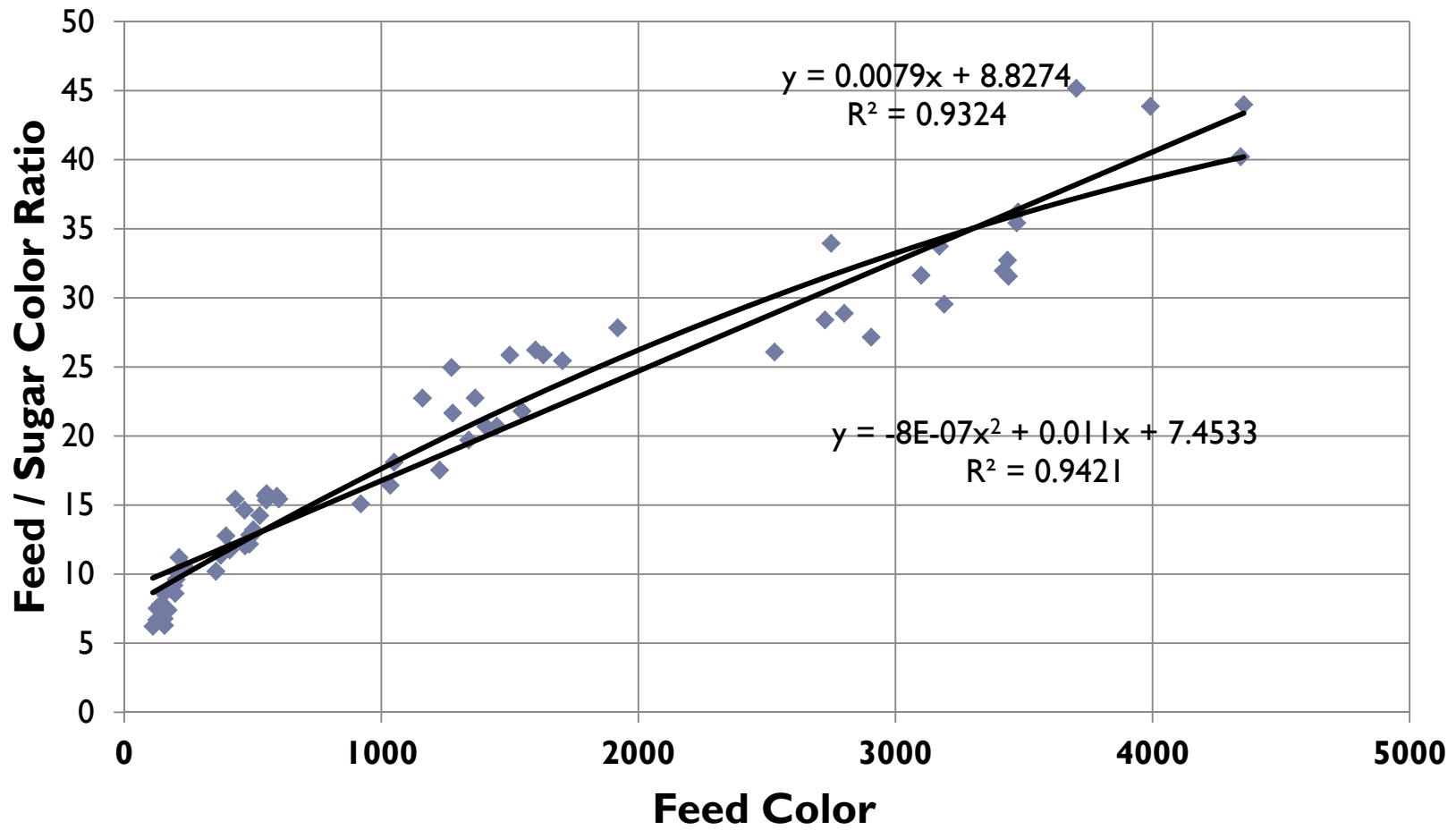
Hulett's Refinery Feed / Sugar Color Ratio



USC Sugar Color vs. Feed Color

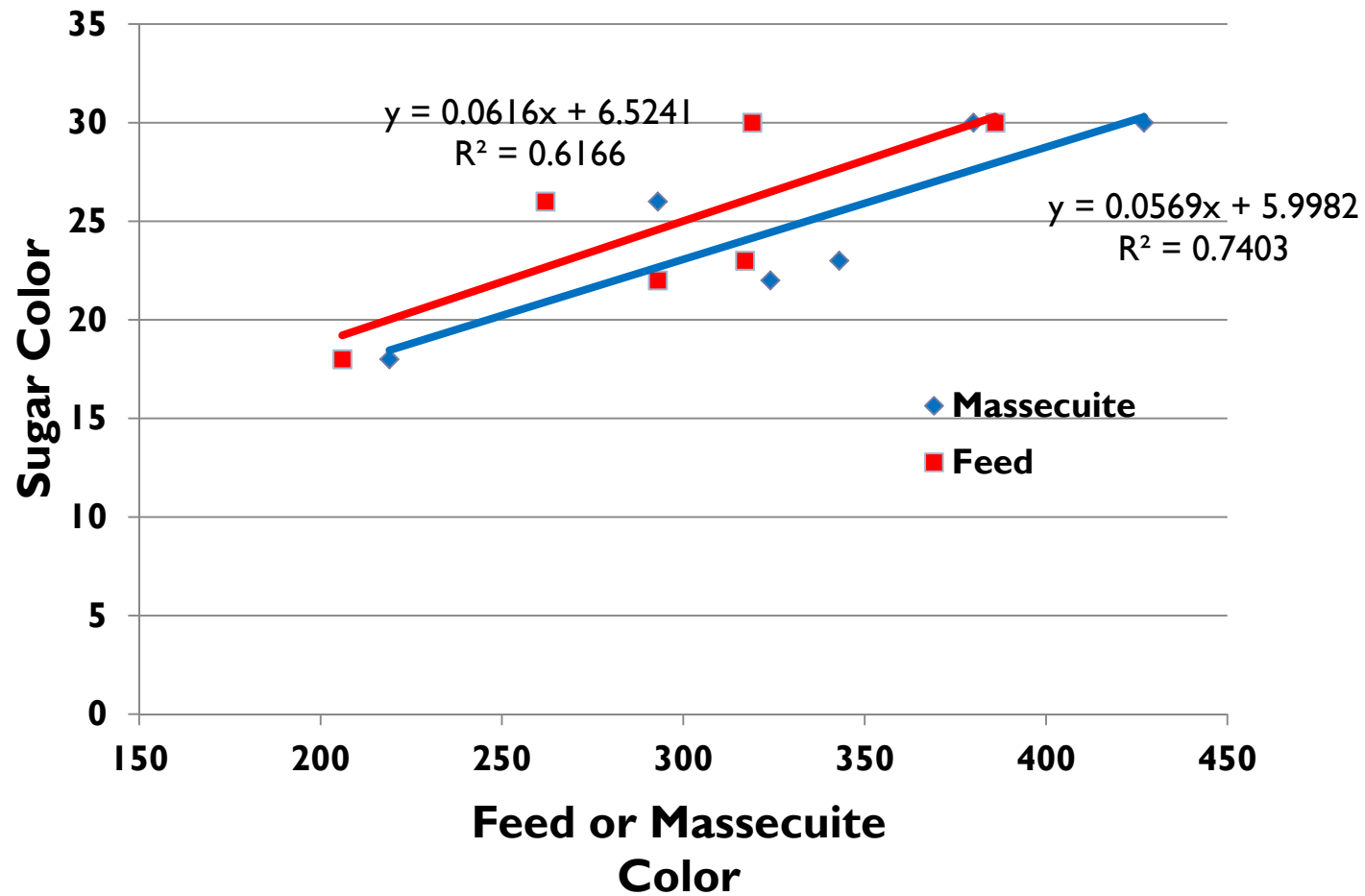


USC Color Ratio- Feed/Sugar

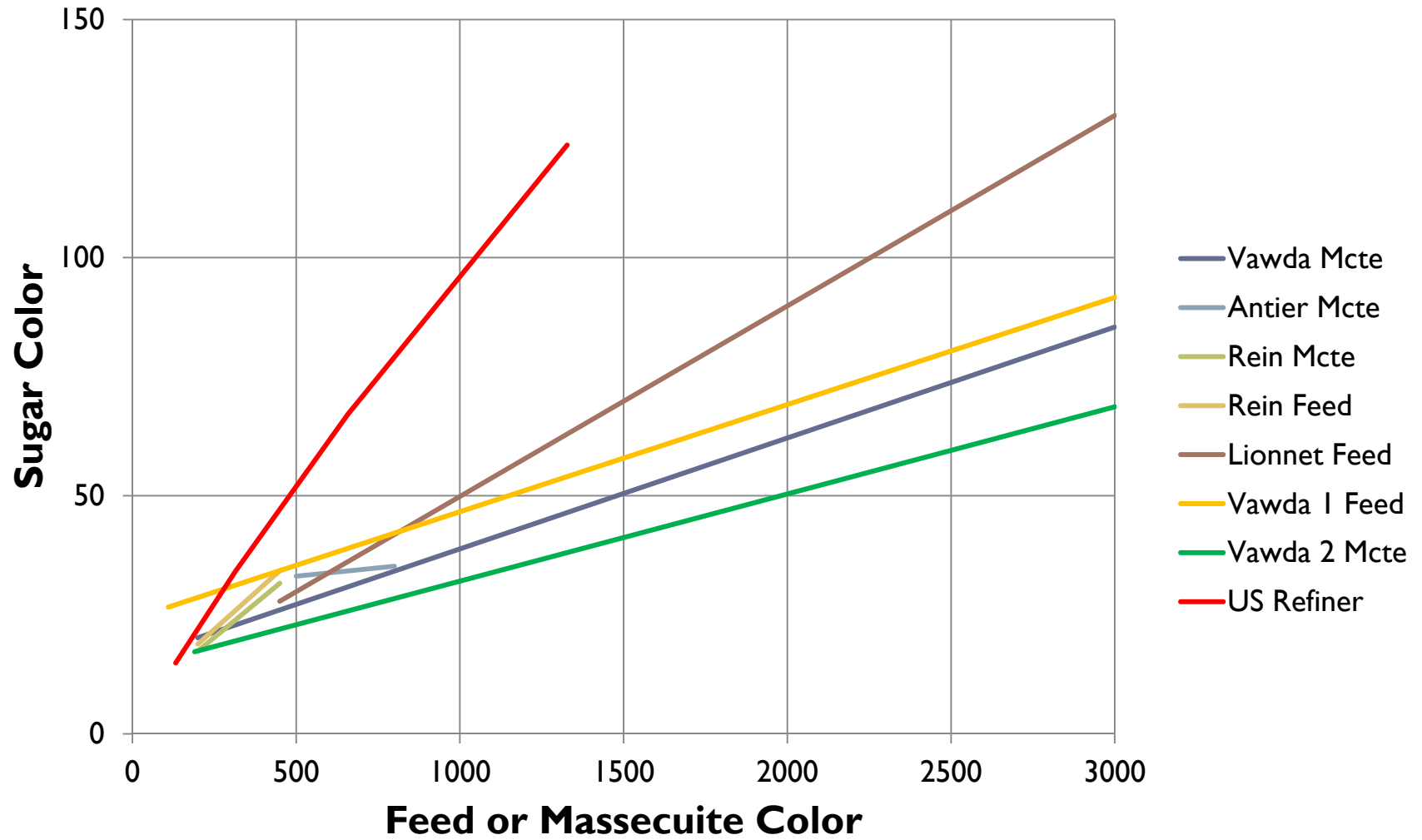


Sugar Color vs. Feed or Massecuite Color

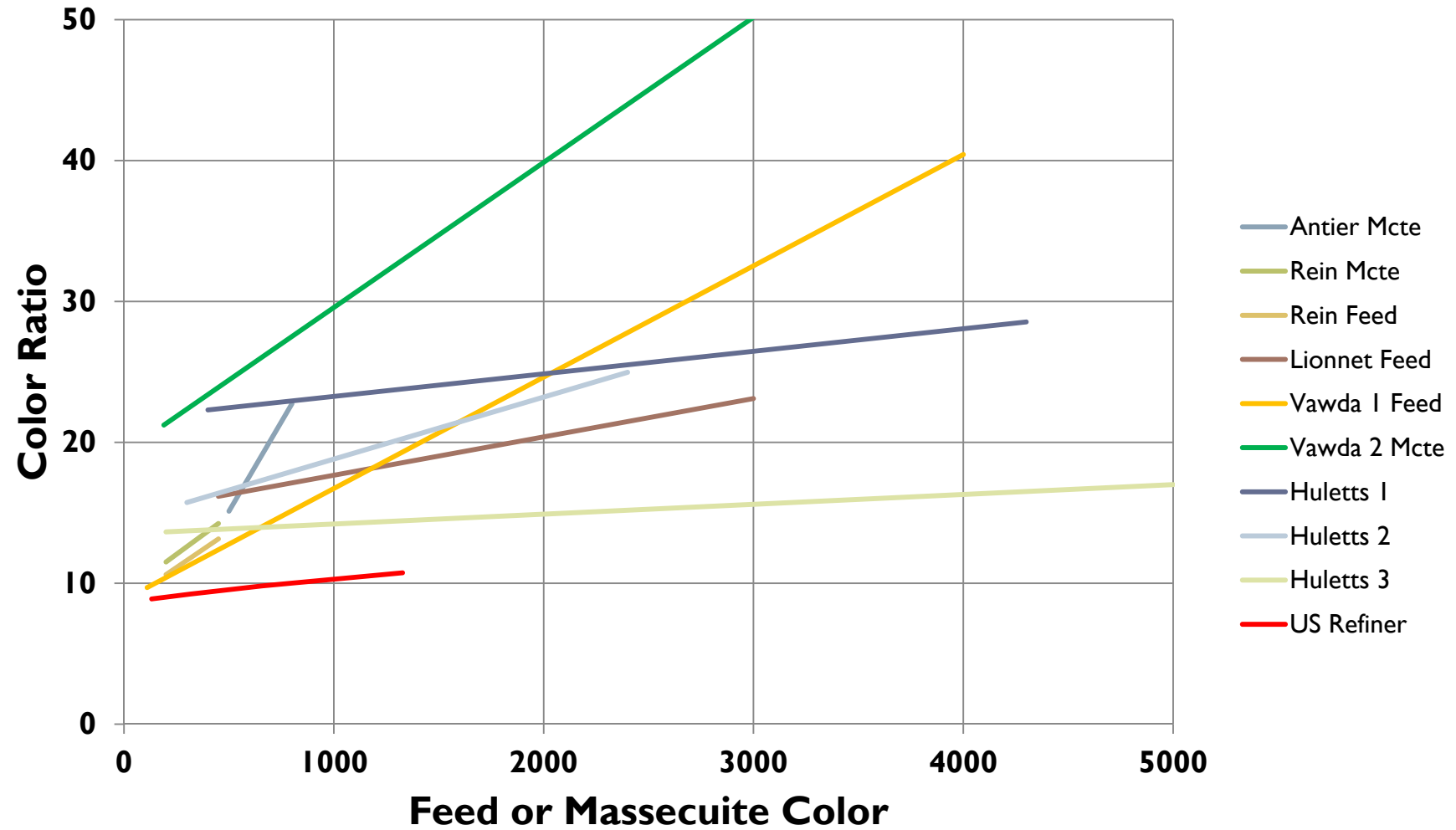
(ref. Rein SPRI 1990)



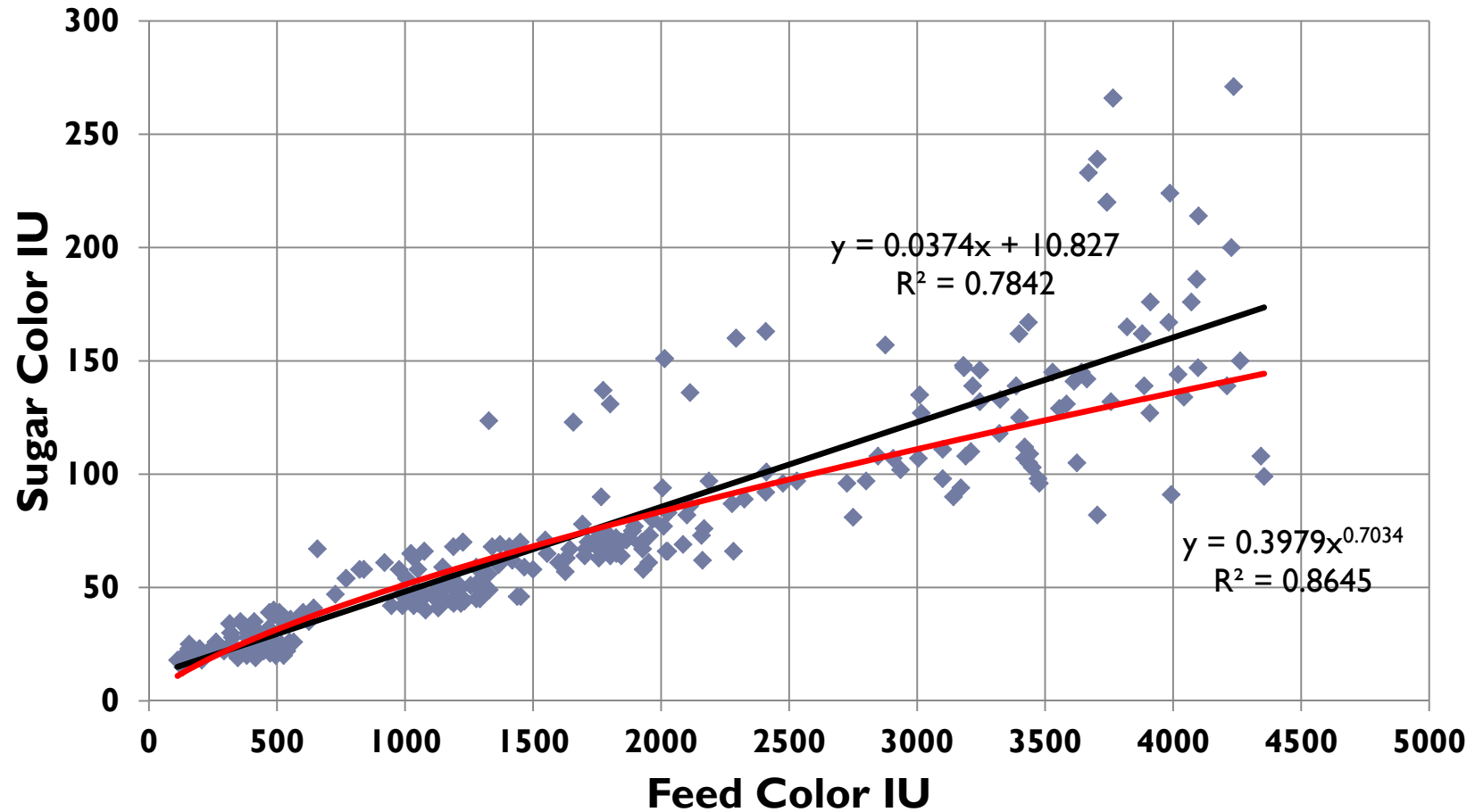
Sugar Color – all data



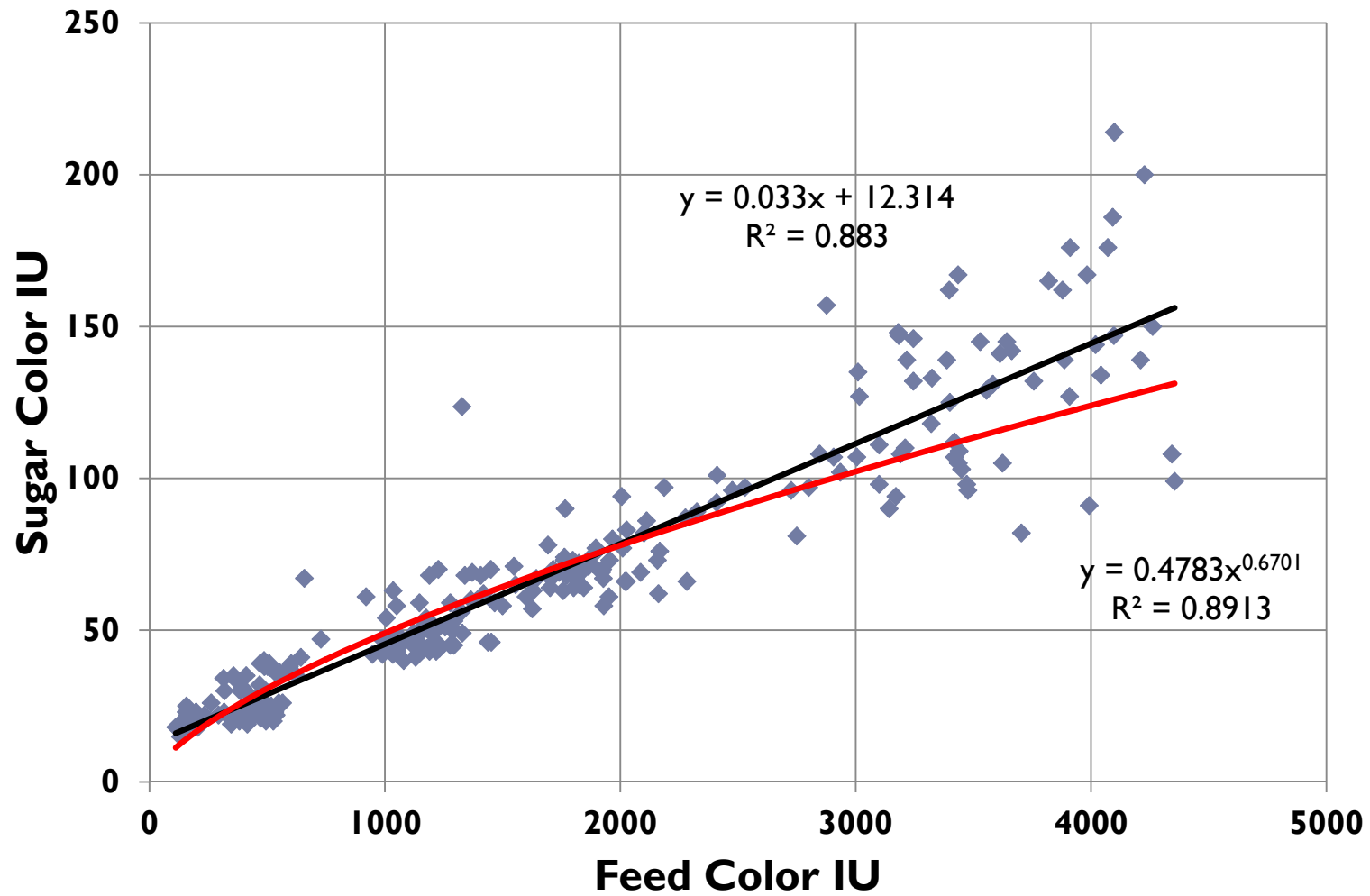
Color ratios – all data



Sugar color vs. feed color – all data



Sugar color vs. feed color – excl. Hulref set 1



Why are there such large differences?

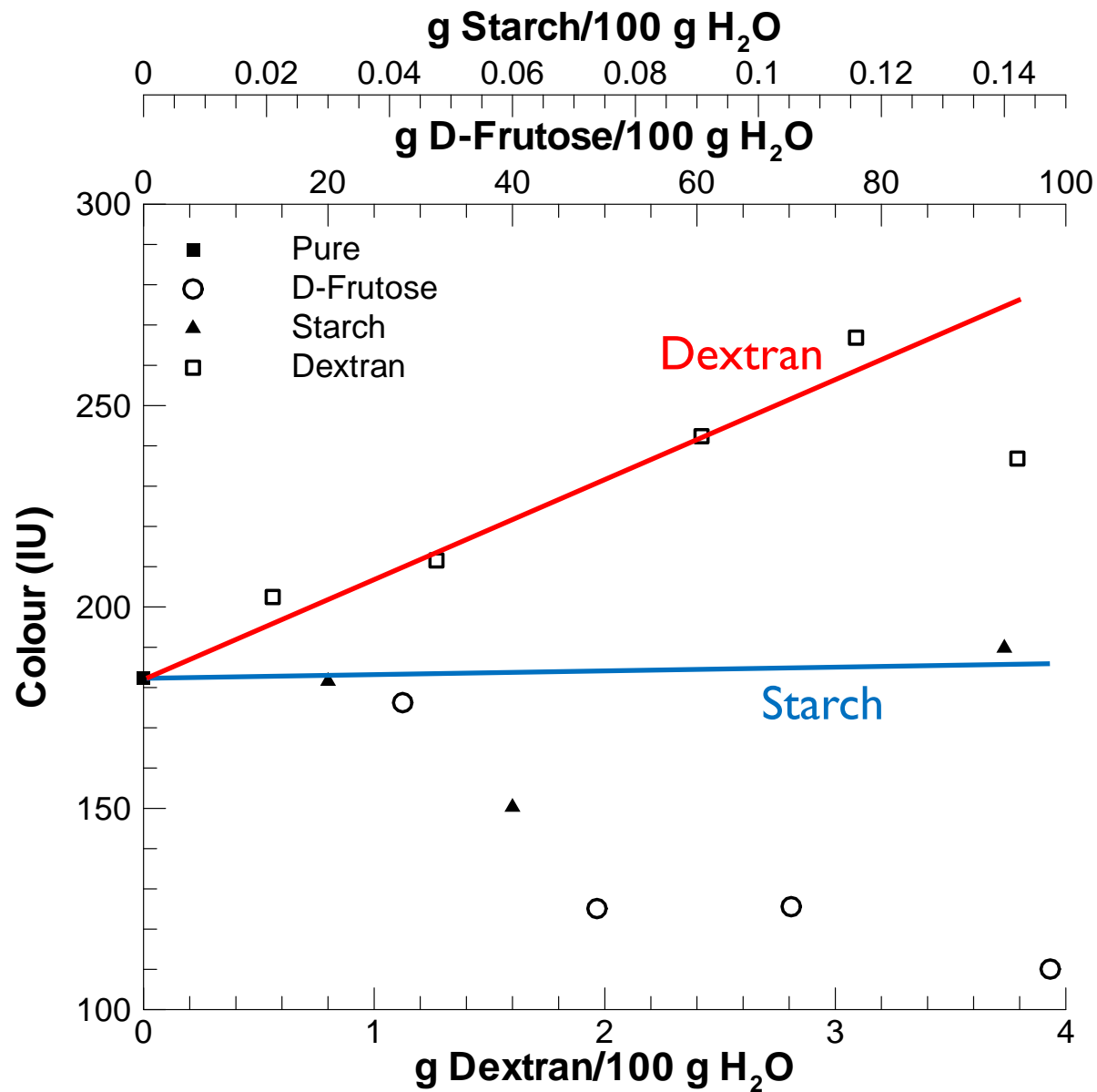
- ▶ The Huletts data is generated mostly in older design pans with higher pressure calandria steam pressure.
- ▶ The US refinery data is generated in pans boiling very fast, and producing a smaller crystal
- ▶ The USC data is generated in modern design pans with lower pressure calandria steam, and part in a continuous pan

Factors which could affect color

- ▶ **Circulation**
 - ▶ Pan design
 - ▶ Stirrer design
- ▶ **Temperature**
 - ▶ Color formation
 - ▶ Rate of crystallization
- ▶ **Nature of impurities**
- ▶ **Size of crystal**
- ▶ **Quality of the sugar – MA and CV**
- ▶ **Quality of control/operation**

Color inclusion in sugar crystals

- ▶ High molecular mass compounds are more likely to be included in the sugar crystal, especially those associated with polysaccharides.
- ▶ High molecular mass polysaccharides have a greater tendency to co-crystallize with sucrose and these polysaccharides can complex with colorants and incorporate them into the crystal



Ref: Sucrose crystallization - Impurity effect on color adsorption.

(Ferreira, Martins, Faria, Rocha, Polanco, Rein. SIT 2008)

Evaporative light scattering profiles of white sugar before and after affination.

VHMM colorants unaffected by affination, MMM colorants reduced (Low MM not measured).

Bento (2009)

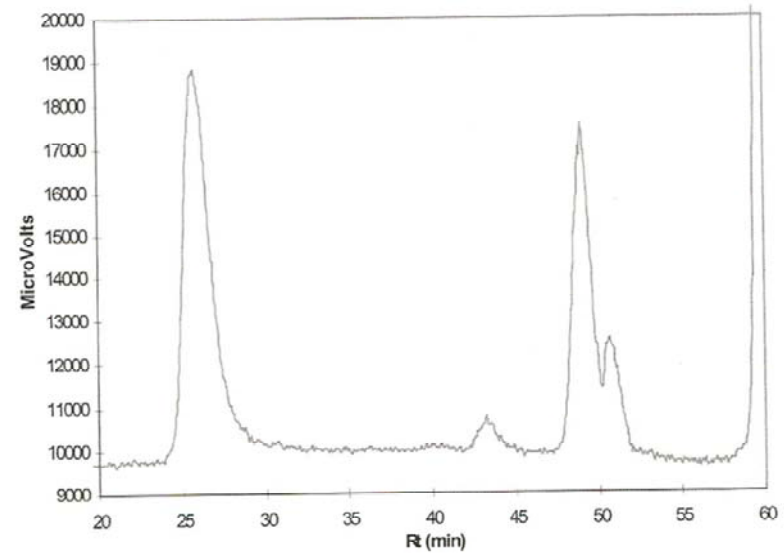


Fig. 19: ELS diagram of cane white sugar

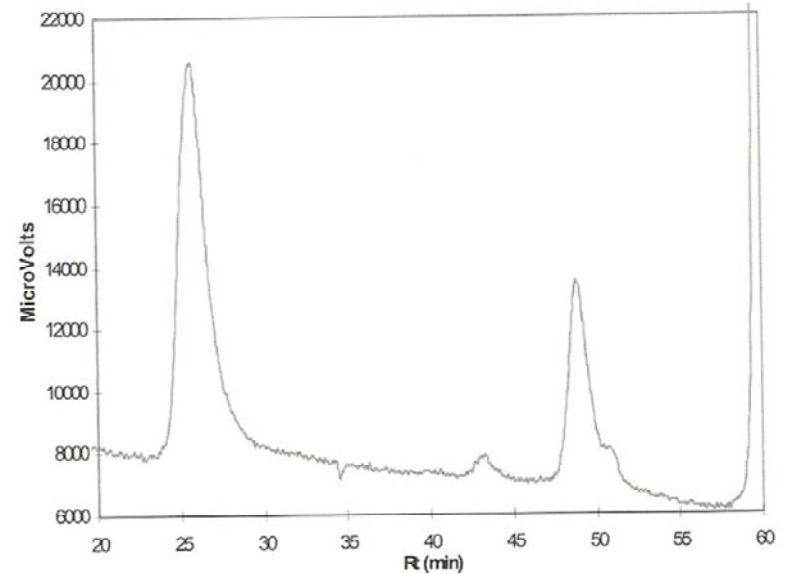


Fig. 20: ELS diagram of cane white sugar (after washing)

Pan design

- ▶ Low head
- ▶ Stirrer
- ▶ Short tubes
- ▶ Tube diameter – 3” or 4”?
- ▶ Straight sides – no body flaring

Color inclusion in sugar crystals

- ▶ In a cane sugar refinery, the color of the sugar produced is dependent on the crystallization conditions in the pan and the degree of circulation in the pan.
- ▶ Fast crystallization generally leads to a slightly higher color (ref. *Mantovani et al.*)
- ▶ Larger crystals grow faster
- ▶ Color formation is dependent on time and temperature.
- ▶ Sugar Refining Handbook recommends operating temperature ± 63 °C. How does this compare?
- ▶ Color transfer from refinery liquor to affinated crystal is 20 % lower when sulfitation has been used (lab trials - *Lionnet 1990*)

Typical average color ratios (massecuite / sugar)

	Massecuite color (IU)	Sugar color (IU)	Ratio
Raw sugar	20000	1300	15
Refined cane sugar	300	18	17
PWS (India)	11000	100	110
PWS (Mauritius)	11000	325	34
Beet sugar	1800	16	110

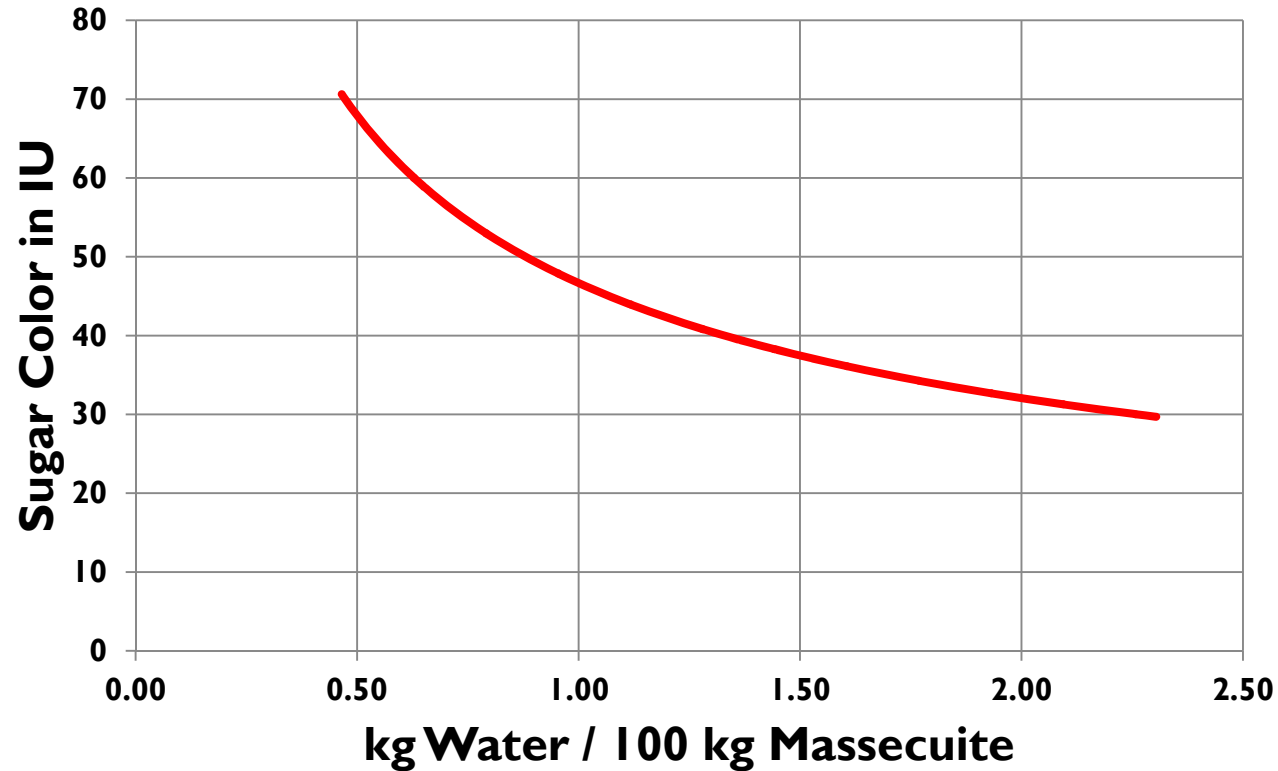
Effect of SO₂ on color

- ▶ Effects not well known
- ▶ It is a reducing agent and antimicrobial
- ▶ Double conjugated bonds that absorb visible radiation become saturated
- ▶ HMW colorants are suspected to be broken down to lower molecular mass colorants
- ▶ May destroy some polysaccharide
- ▶ May break the colorant-polysaccharide complex
- ▶ May inhibit formation of color e.g. *Maillard* reaction, browning reactions.

Refinery crystallization

- ▶ A problem experienced in white boilings that is not often encountered in the raw house is the formation of conglomerates, which trap liquor in the crystal. A clean conglomerate-free grain is essential
- ▶ Some color generation occurs during boiling, with massecuite color increases between 8 and 16 %. This is minimized by good pan design and the use of stirrers in pans. Stirrers are considered to be essential, not only to reduce color formation, but also to improve sugar quality and regularity
- ▶ Crystal size – large favors centrifuging, small crystallization?
- ▶ CV of sugar also affects centrifuging

Centrifugal washing



For beet white sugar, water used in range 1.2 to 7.6 kg water/100 g massecuite (Ref. *vd Poel et al.*)

Finally

- ▶ Any other data available to add to data base?
- ▶ Any other effects?
- ▶ How can we generate a relationship taking all factors into account?