Approaches to Treatment Optimization of Humics in Wastewater: 'DOE' Vs 'OFAT'

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Content

1. Background
2. What We Did & How
3. Process Optimization
4. Conclusions

Fresh-Cut Agricultural Produce

- Any fruit or vegetable that undergoes minimal or no processing after harvest






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Fresh-Cut Agricultural Industry

PRODUCTION

Growth & Harvest

PROCESSING

Washed, cleaned, graded & packed

CONSUMPTION

Retail & Eating

Recycle/Re-use

Wastewater Treatment

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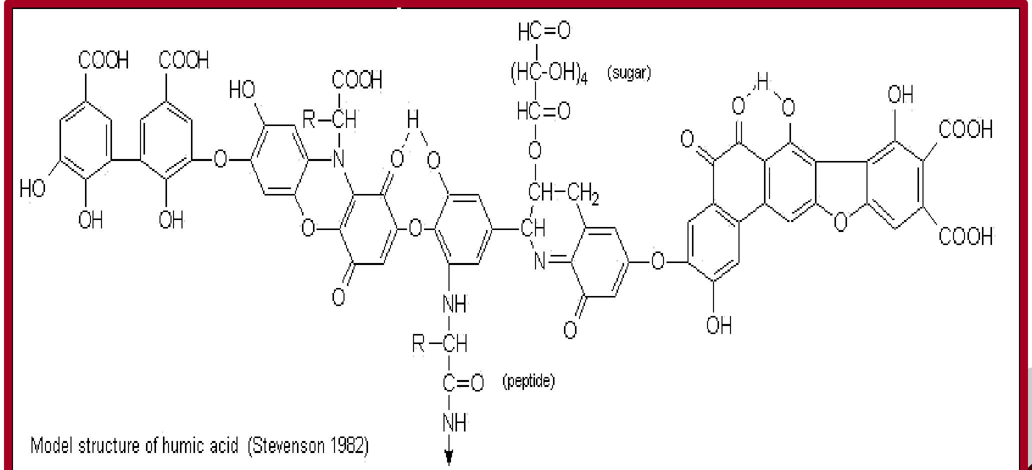
Fresh-Cut Produce Wastewater

- **High amount of organic load**
  - **Field soil**
  - **Plant debris**
  - **Soil particles**
  - **Salt**
  - **Pesticide residues**

- **Humic substances**



Model structure of humic acid (Stevenson 1982)

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What the Legislation Says?

- Reuse and recycling of wastewater is supported by European Union (Council Directive, 1991; 1998; EU, 1996)

- Use of alternative water qualities is justified
  - Reuse must not compromise sanitation
  - Reuse must not cause adulteration of the product

- Wastewater reuse in food industries for washing purposes only
  - Wastewater must be treated by an **advanced treatment system**
  - Product, facilities, equipment, and utensils must undergo a separate final rinse with fresh portable water (USDA, 1999)

Advanced Oxidation

- **Advanced Chemical Oxidation**
  - Heterogeneous Catalyst

http://www.tucsonaz.gov/water/aop

Lab scale → Pilot scale → Commercial scale

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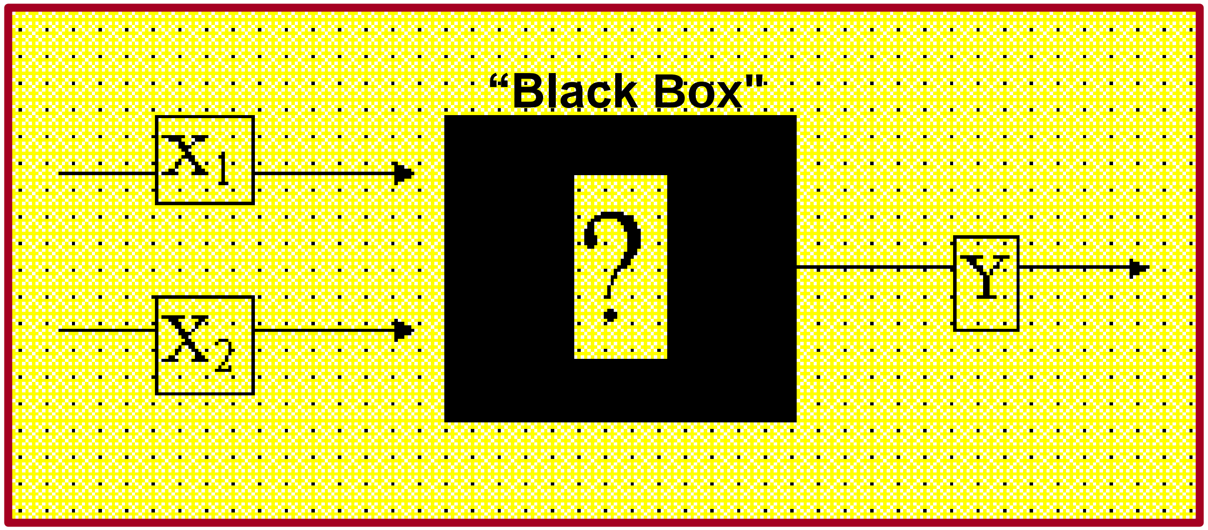
Experimental Optimization



- Wastewater (humics)
- Catalyst
- H_2O_2
- pH

Chemical process
(Catalysis)

Treated wastewater

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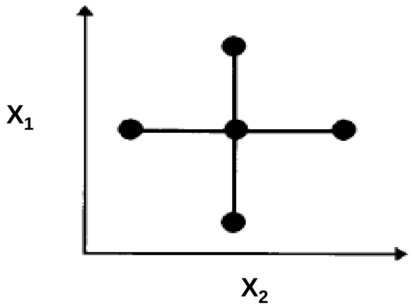
Optimization Approaches

- **'One Factor at a time' (OFAT)**

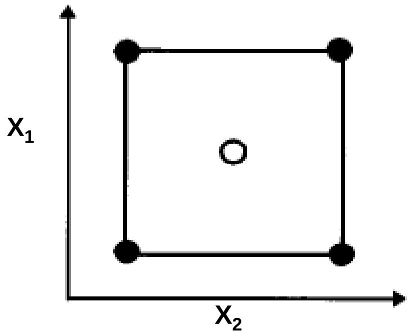
  -Main-Effects Model: $Y_1 = X_1 + X_2$

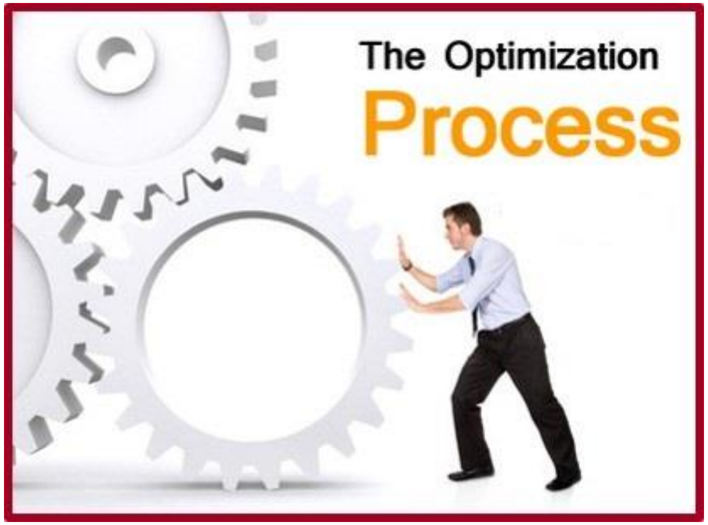


- **Design of experiments (DOE)**

  -Statistically vary factors simultaneously

  Interactions Model: $Y_1 = X_1 + X_2 + X_1*X_2$





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What We Did

Compared a statistical design of experiment (DOE) and one factor at a time (OFAT) approach in the optimization of humics contaminated water

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The Questions

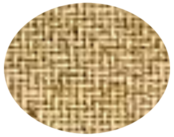
Will the DOE and OFAT approach provide the same optimum treatment condition for humics?

Which approach is better?

- Treatment efficiency
- Faster
- Cost savings

How We Did It

+



PAN Catalyst

+

Hydrogen Peroxide

- Bench scale experiments
- Simulated Humic acid contaminated water (25mg/L)
- Key parameters
  - pH
  - H_2O_2 concentration
  - Mass of Catalyst
- UV/Vis – Humic acid
  - Aromaticity @254 nm
  - Colour @400 nm
- HPLC-UV – H_2O_2

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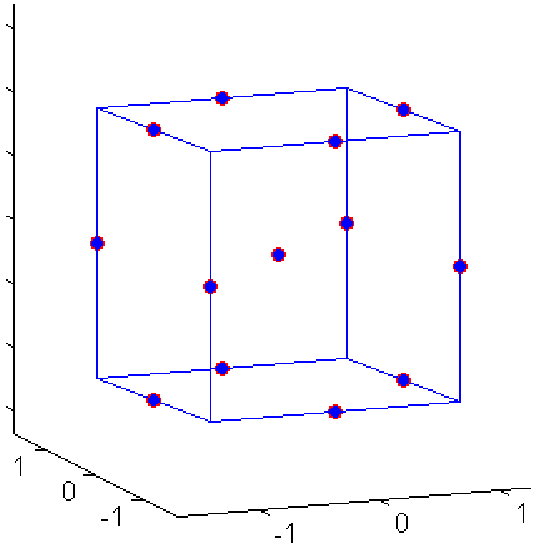
How We Did It

- **The Box–Behnken design**
- **JMP Pro 11 software**

Key Parameters	**Levels**		
	Low (−1)	**Center** (0)	**High** (+1)
Mass of Catalyst (g)	***3***	***5***	***7***
H_2O_2 (mg/L)	***50***	***550***	***1000***
pH	***3***	***5***	***7***
Responses	**Goal**		
% Degradation of Humic acid @ 254nm	**Maximize**		
% Degradation of Humic acid @ 400nm	**Maximize**		

How We Did It

- **The Box–Behnken design**
  - 15 experiments
  - 3 replicated center points



Run	Mode	Key Parameters		
		Catalyst (g)	H_2O_2 (mg/L)	pH
1	+ 0 +	7	550	3
2	0 + -	5	1000	3
3	0 - -	5	100	3
4	- 0 -	3	550	3
5	- - 0	3	100	5
6	+ + 0	7	1000	5
7	- + 0	3	1000	5
8	+ - 0	7	100	5
9	0 + +	5	1000	7
10	0 - +	5	100	7
11	+ 0 +	7	550	7
12	- 0 +	3	550	7
13	0 0 0	5	550	5
14	0 0 0	5	550	5
15	0 0 0	5	550	5

(25mg/L HA; Temp 22 ± 1^0C)

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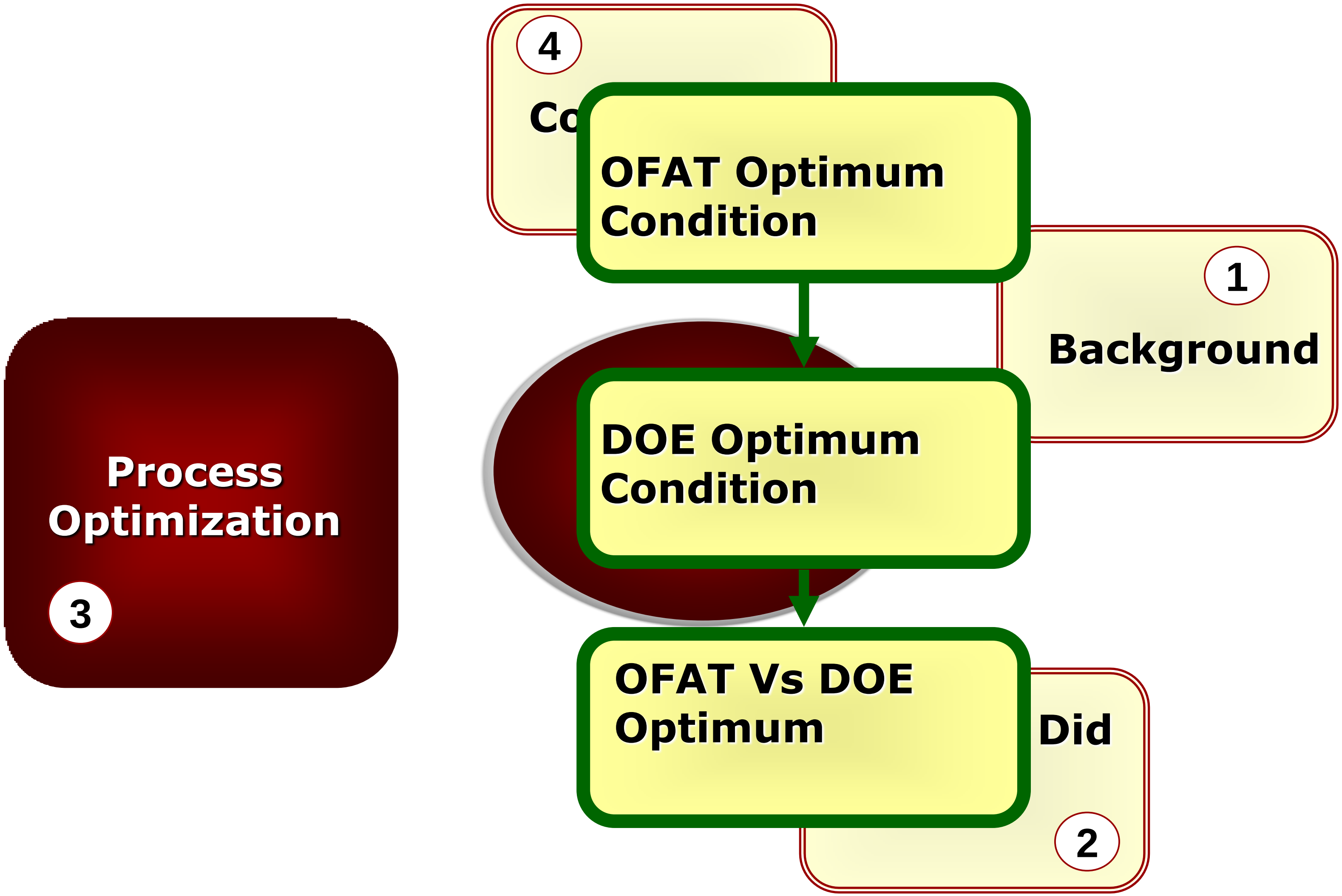
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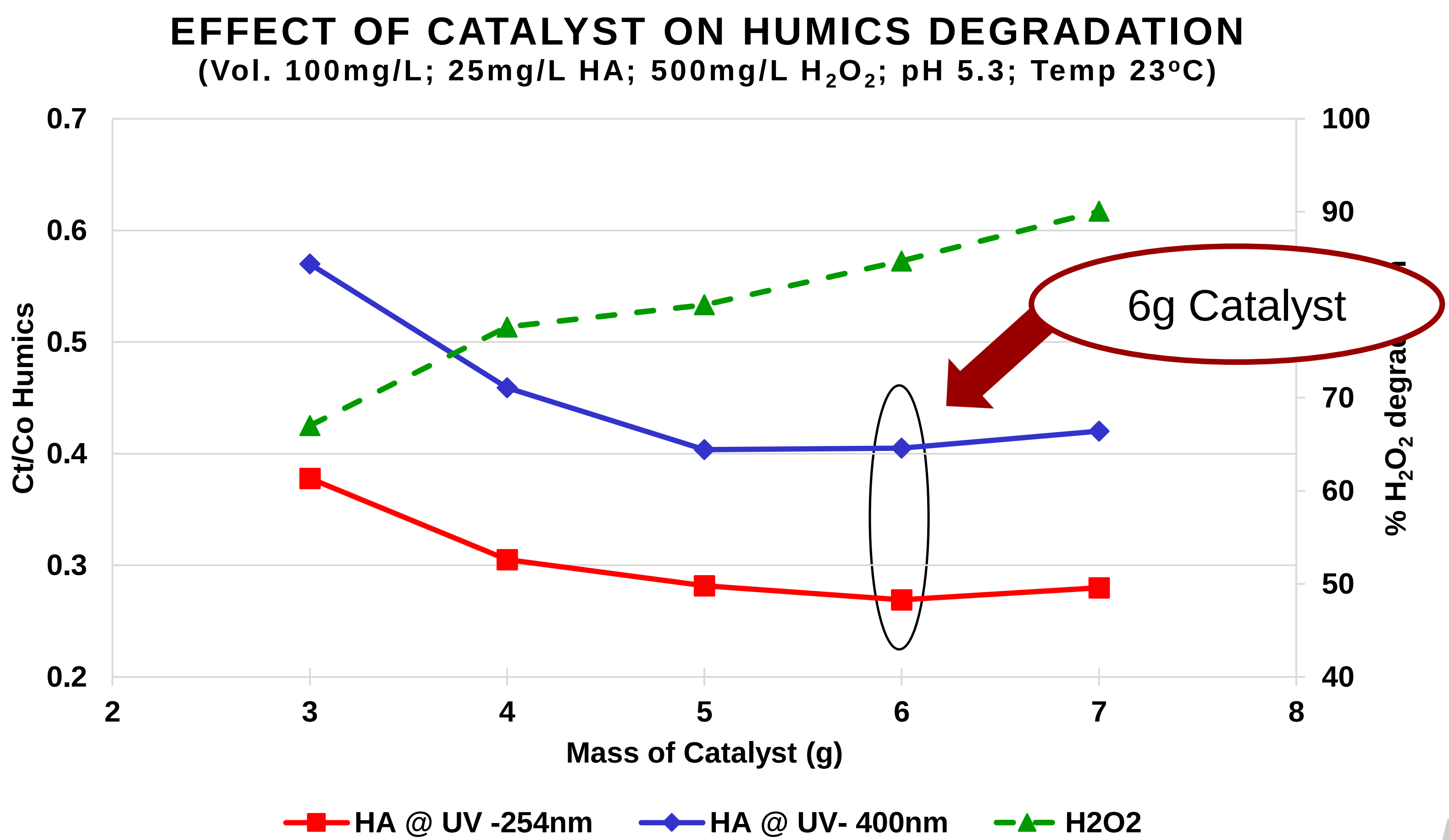
Co
OFAT Optimum Condition
1
Background
Process Optimization
3
DOE Optimum Condition
OFAT Vs DOE Optimum
Did
2

OFAT Optimum Catalyst



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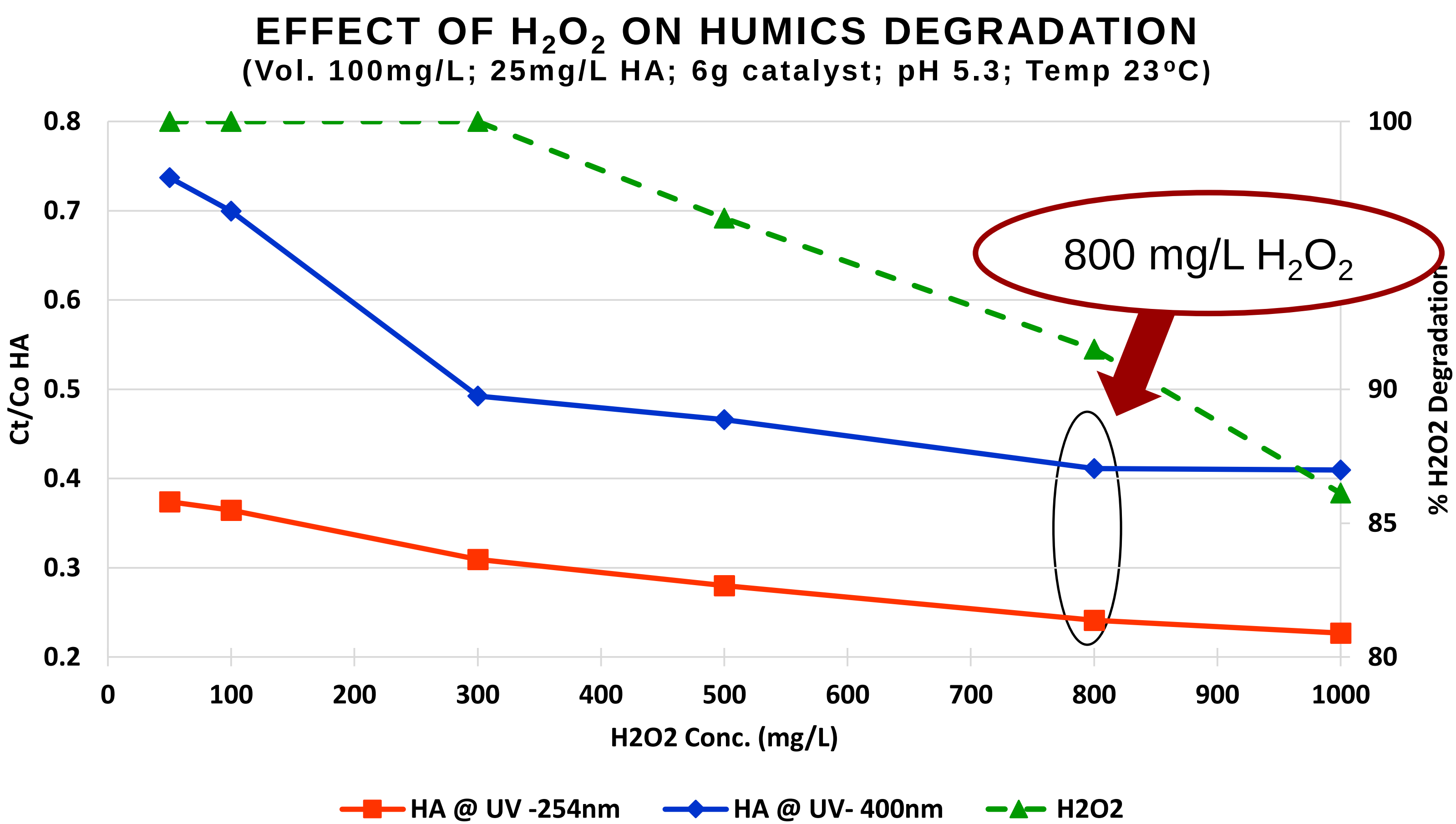
OFAT Optimum H_2O_2



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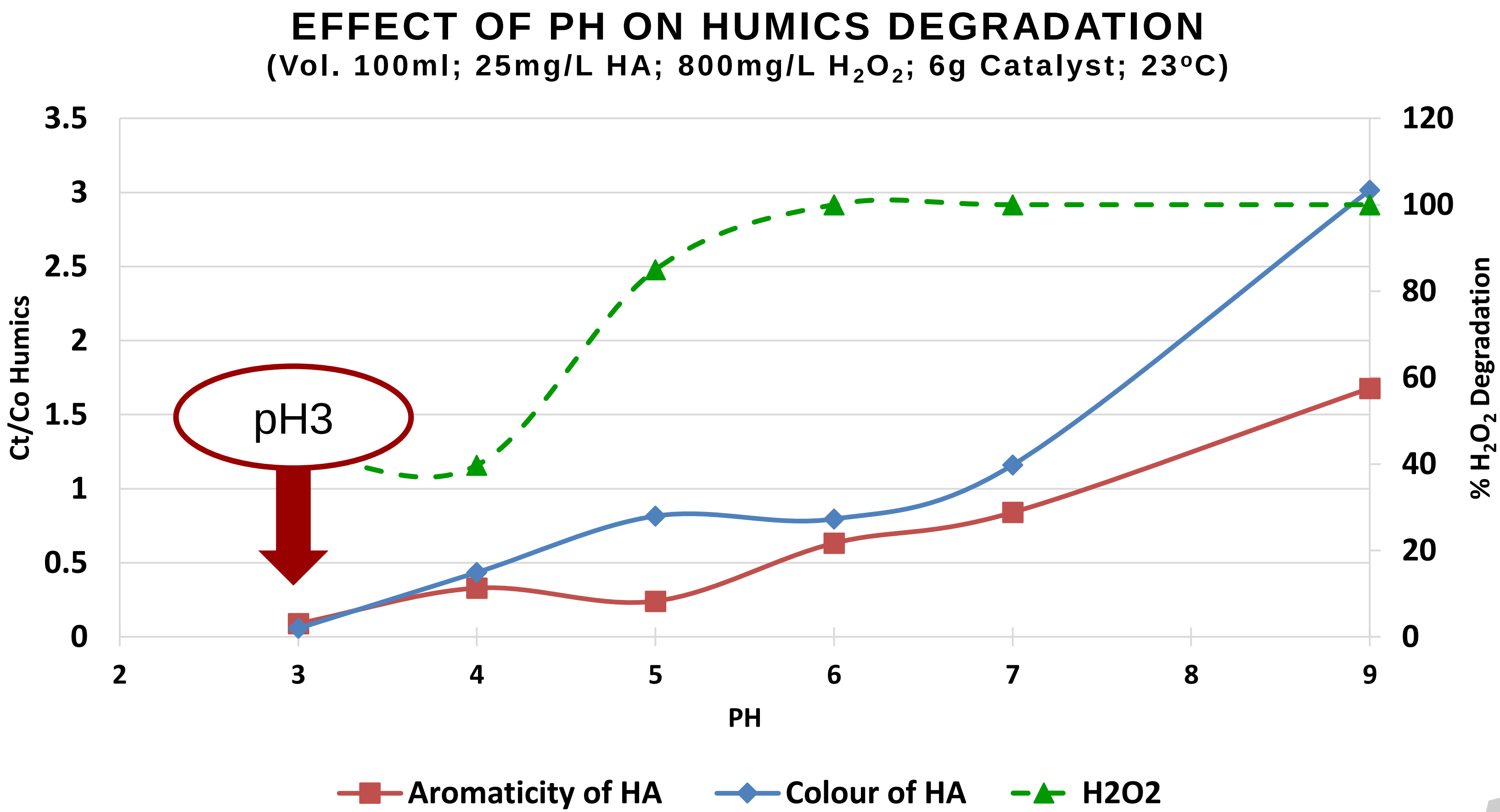
OFAT Optimum pH



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OFAT Optimum

pH 3

6g Catalyst

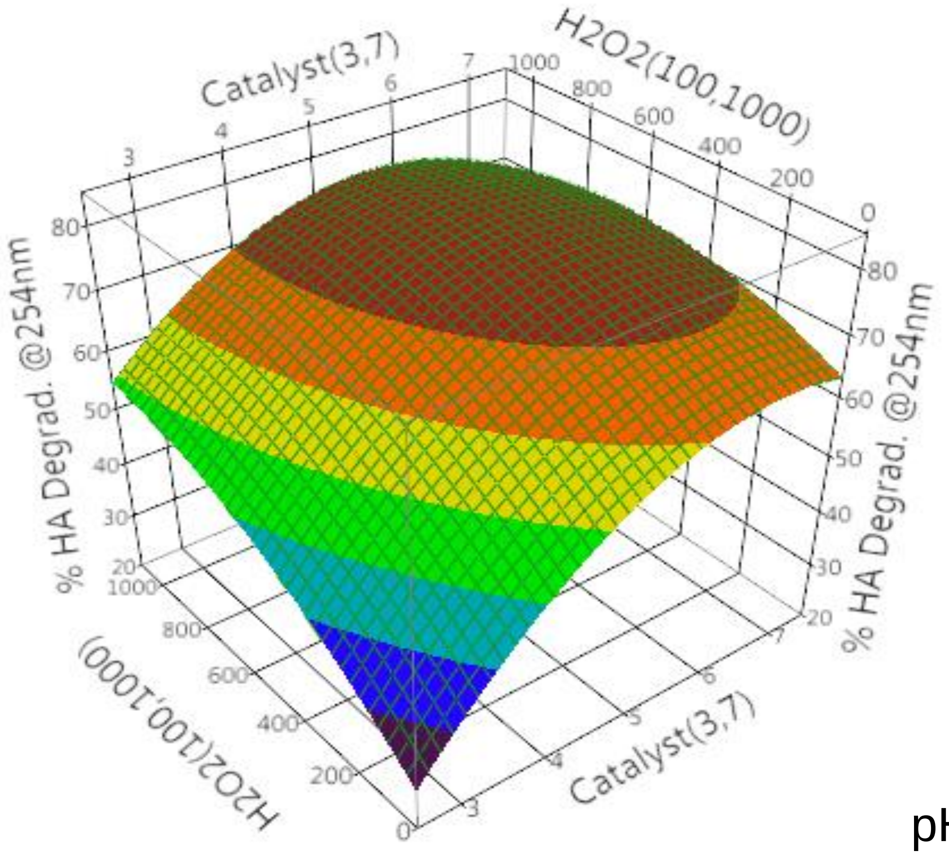
+

800mg/L Hydrogen Peroxide

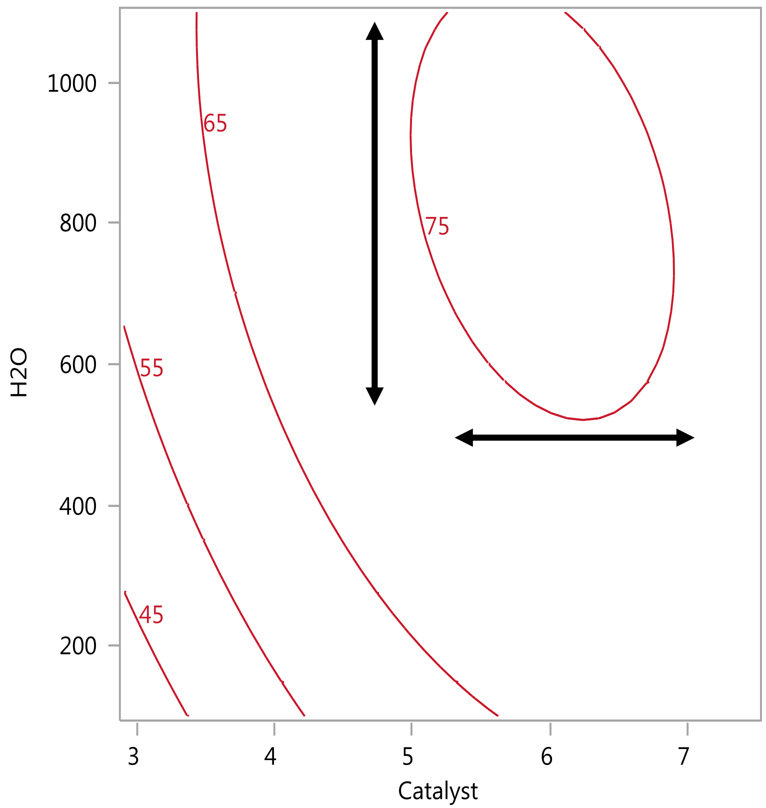
89.2% aromaticity

94.2% colour

DOE Optimum Catalyst



pH5



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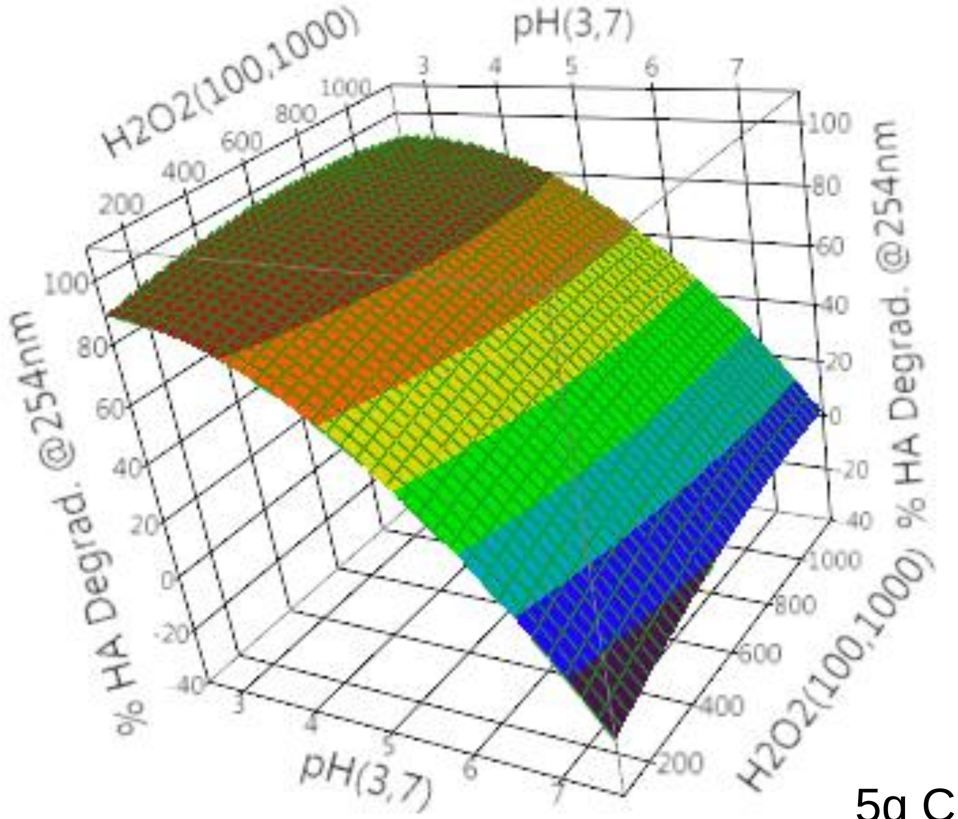
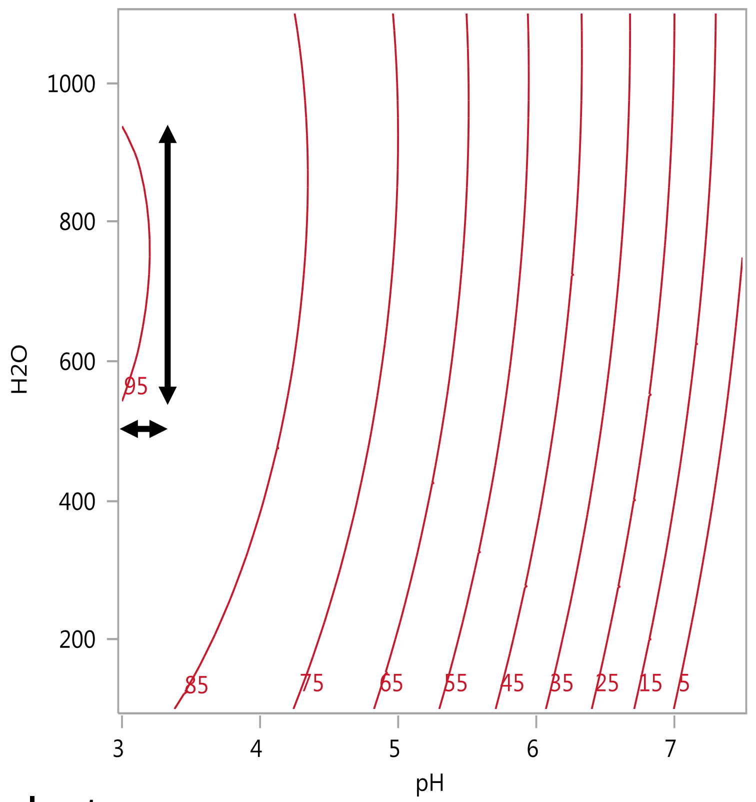
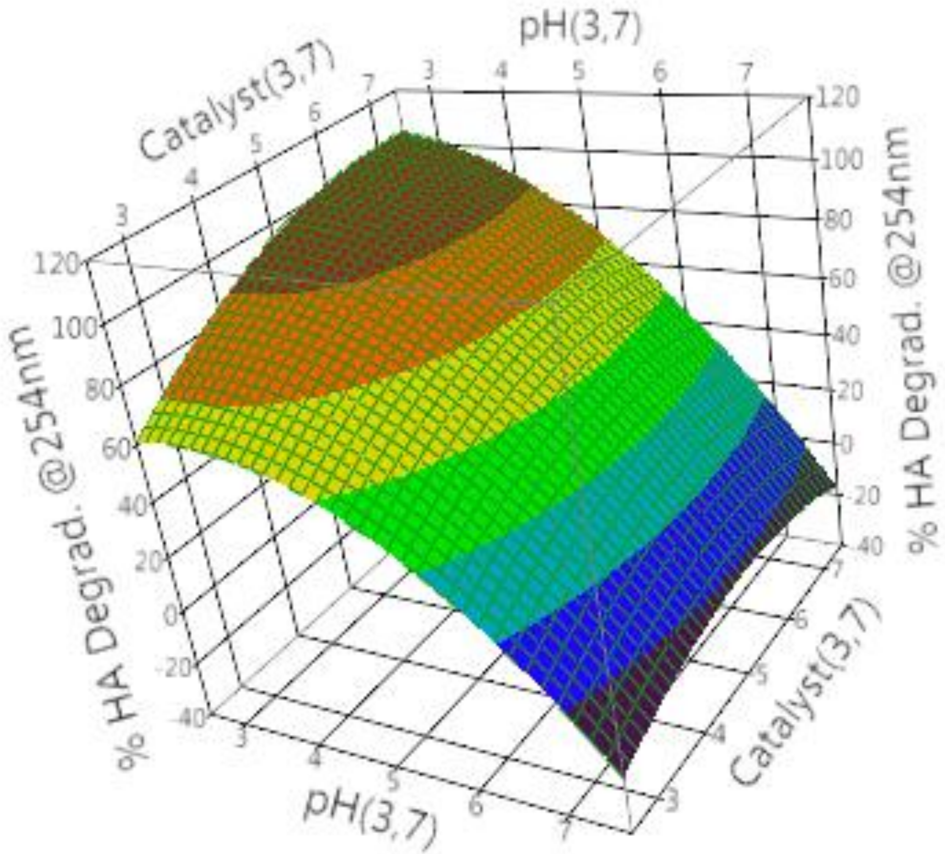
DOE Optimum H_2O_2

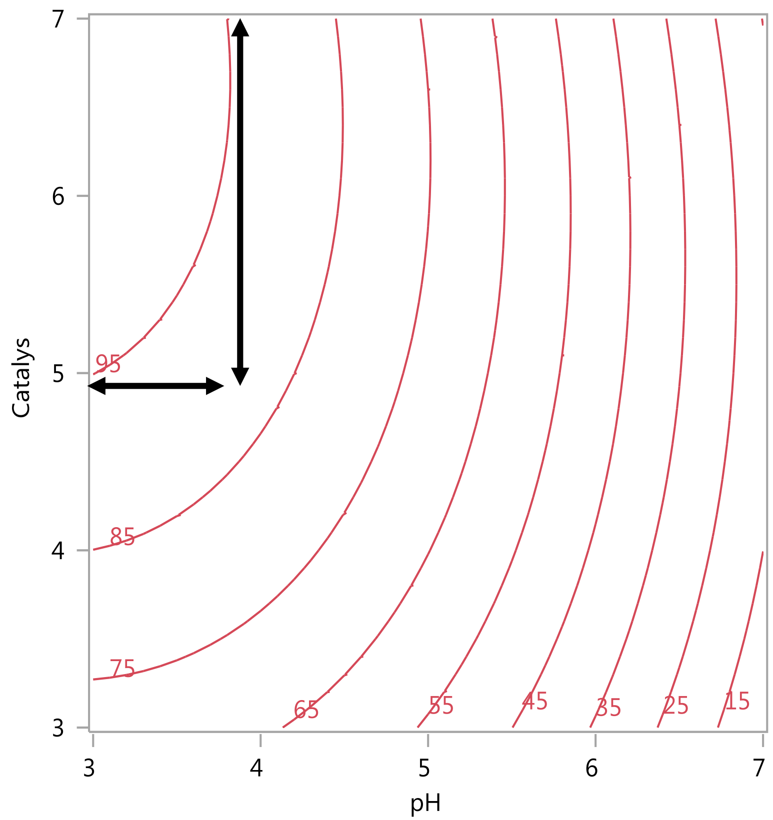




5g Catalyst

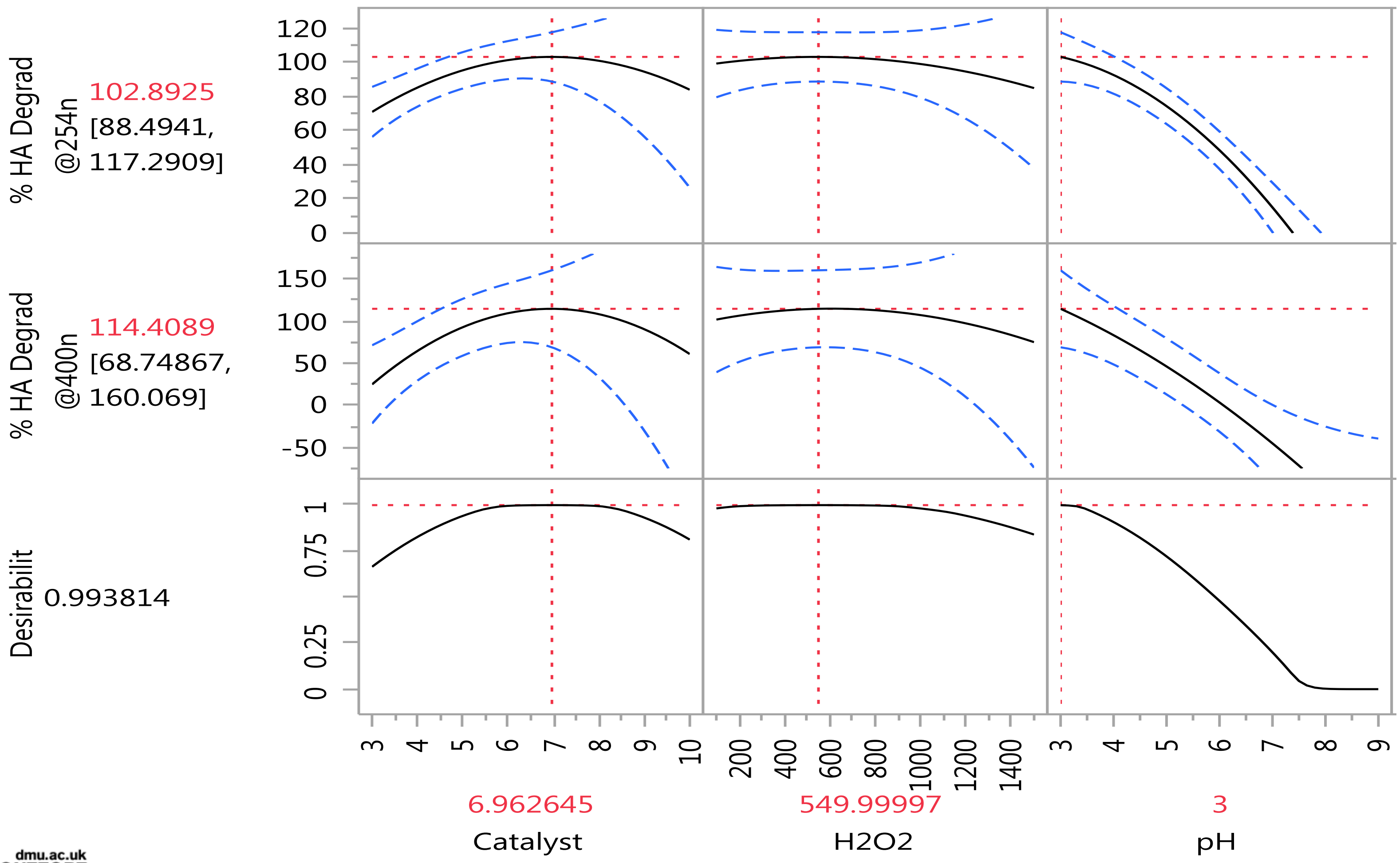
DOE Optimum pH





550mg/L H_2O_2

DOE Optimum



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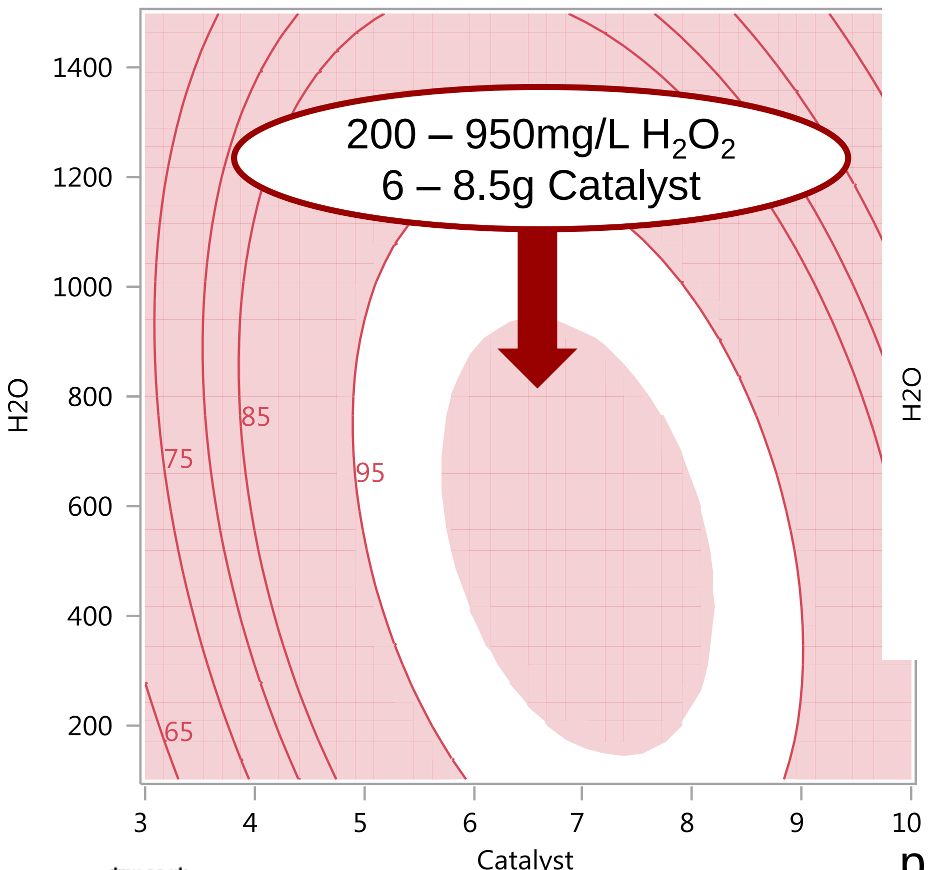
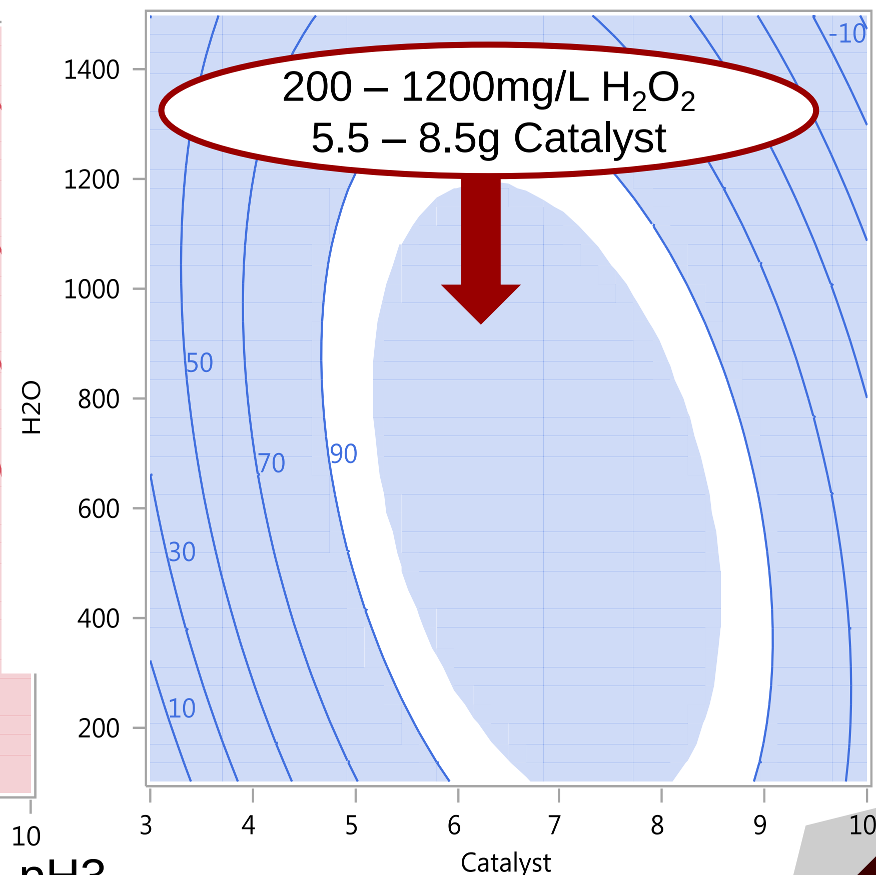
DOE Optimum

Aromaticity

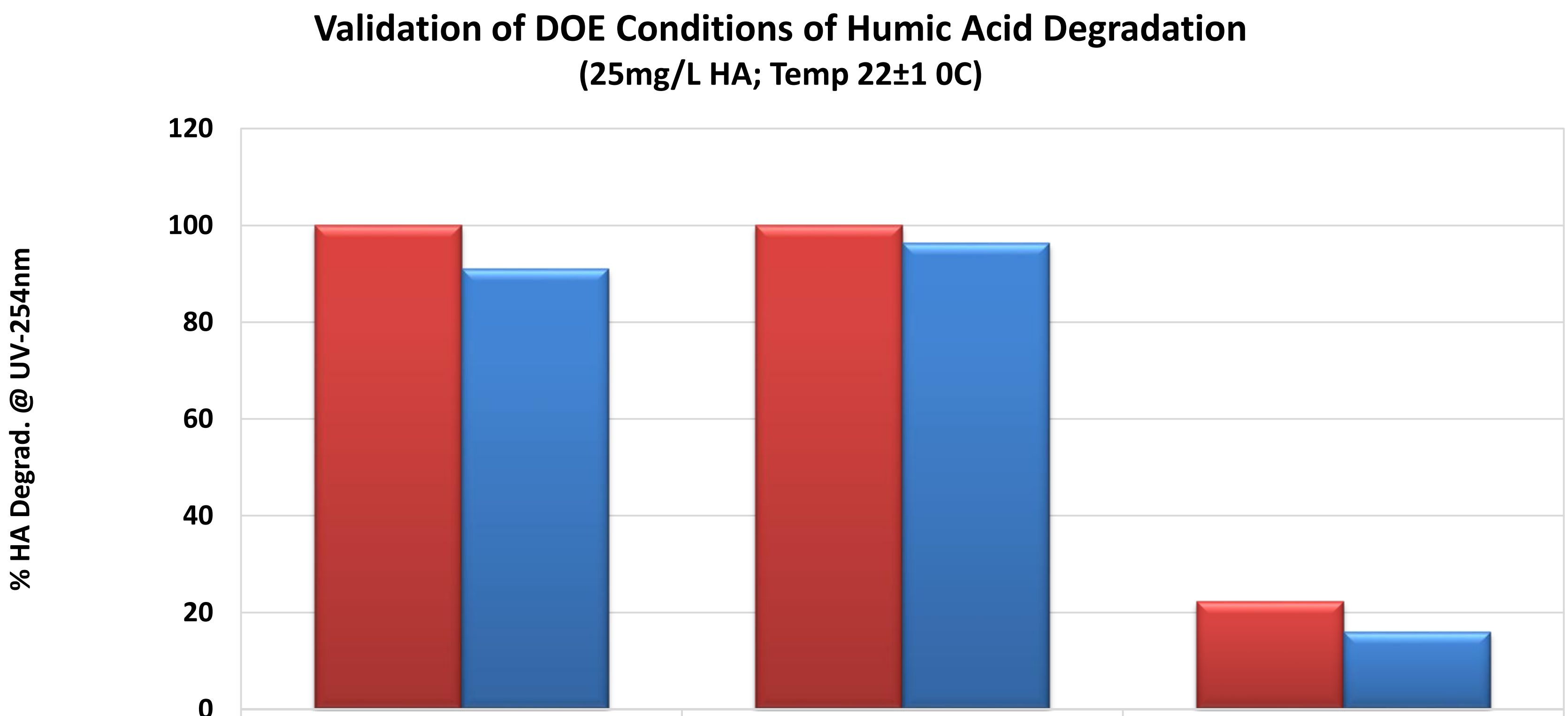


Colour



pH3

Validation of DOE



	6g Cat; 800mg/L H2O2; pH3	7g Cat; 550mg/L H2O2; pH3	6g Cat; 800mg/L H2O2; pH7
DOE Prediction	100	100	22.3
Exp. Result	91	96.33	16

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OFAT Vs DOE

OFAT Approach

pH 3

+

6g Catalyst

800mg/L Hydrogen Peroxide

89.2% aromaticity

94.2% colour

DOE Approach

pH 3

+

6 to 8g Catalyst

200 to 800 mg/L Hydrogen Peroxide

91 to 100% aromaticity

100% colour

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Conclusions

Will the OFAT and DOE approaches provide the same optimum treatment condition for wastewater?

OFAT – 800mg/L H_2O_2; 6g Catalyst; pH 3

DOE – Range of conditions:

200 to 800mg/L H_2O_2;

6 to 8.5g Catalyst;

pH 3 to 3.5

Conclusions

Which approach is better?

- The DOE approach to optimization was more robust
  - More information on the design space
  - Cost savings: ≈ 4 folds (75%) savings on hydrogen peroxide

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Thank You