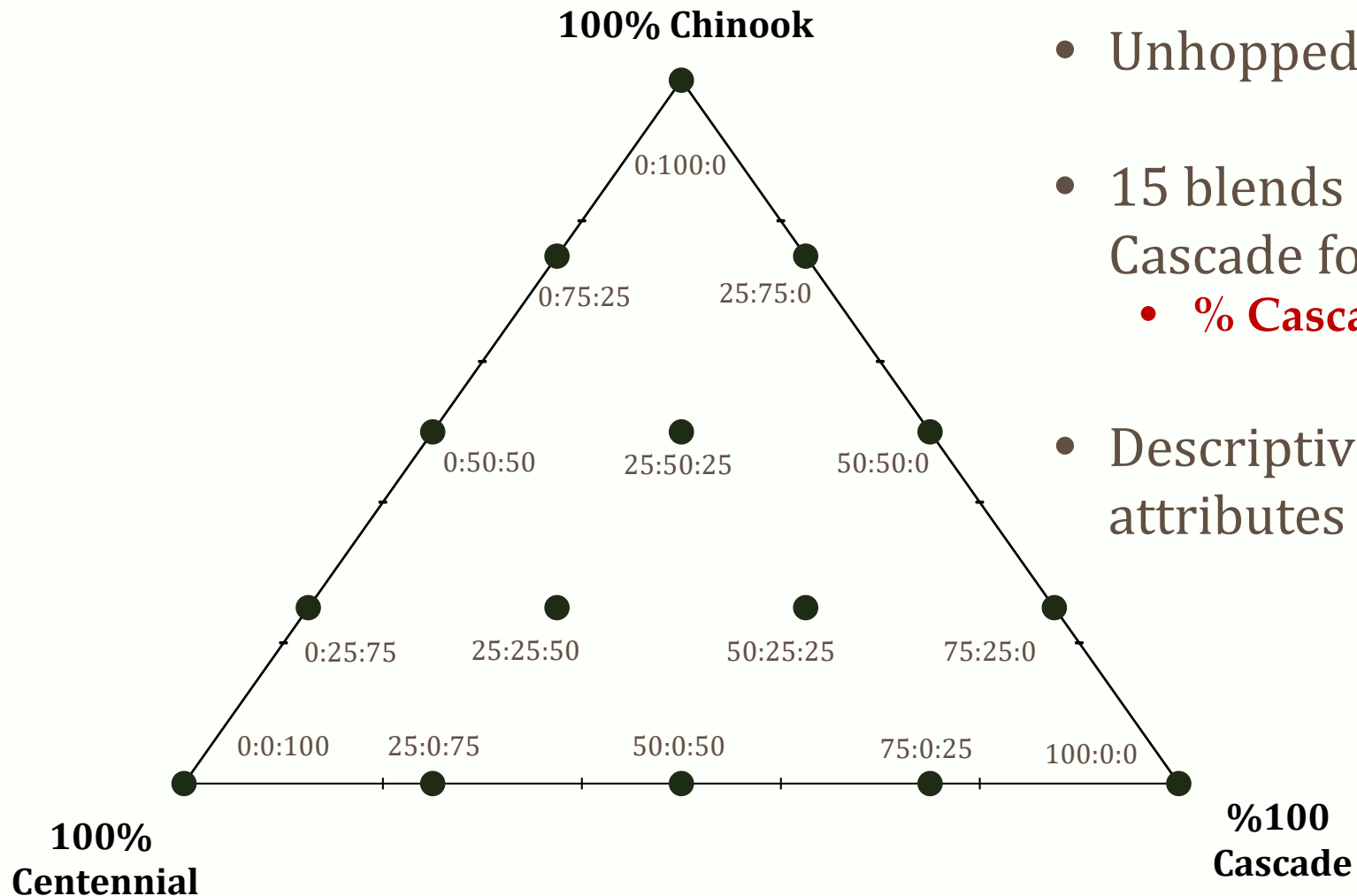


Sensory Directed Mixture Study of Beers Dry-Hopped with Cascade, Centennial, and Chinook

Thomas H. Shellhammer
Oregon State University
2017 Craft Brewers Conference
Brewer's Association Research Update

Sensory directed mixture study design



- Unhopped beer base
- 15 blends of Chinook, Centennial and Cascade for dry-hopping
 - % Cascade, % Chinook, % Centennial
- Descriptive analysis used to scale attributes of these blends

Raw Material and Processing Methodology

Brewing unhopped beer

Beer Specifications:

- Grist:
 - 85% Pale 2-row
 - 13.5% Carmel 10L
 - 0.5% Carmel 120L
- **Original Gravity:** 10.6 P
- **Real Extract:** 3.16 P
- **BU = 20 mg/L (iso-extract)**
- **ABV = 4.8 % ABV**



Hops from 2015 harvest

- Whole cone hops procured from Crosby Hop Farm

	Cascade	Chinook	Centennial
Total Oil (mg/100g)	1.00	1.82	1.93
State Origin	OR	WA	ID
Farm	Crosby	Puterbaugh	Obendorf

Hop Preparation and Dry-Hopping Parameters

Hop Preparation For Dry Hopping

- Blended whole cone hops of Cascade, Chinook and Centennial*
 - Mixed and homogenized by grinding
 - Weighted into different ratios
- *sample also taken for oil analysis*

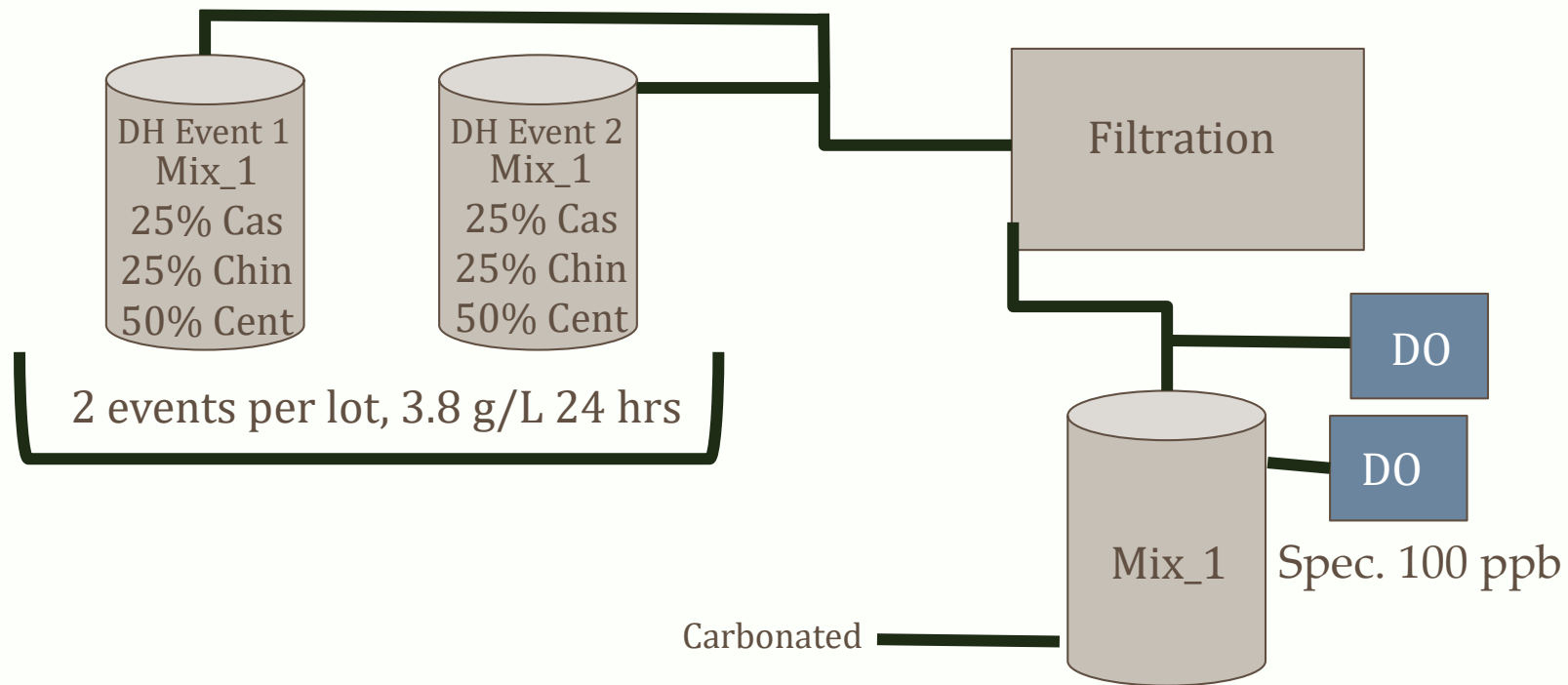
Dry Hopping Parameters

- Added to **40 L** finished beer at **3.8 g/L for 24 hrs**
 - CO₂ blanket during addition
- 18°C during dry-hopping

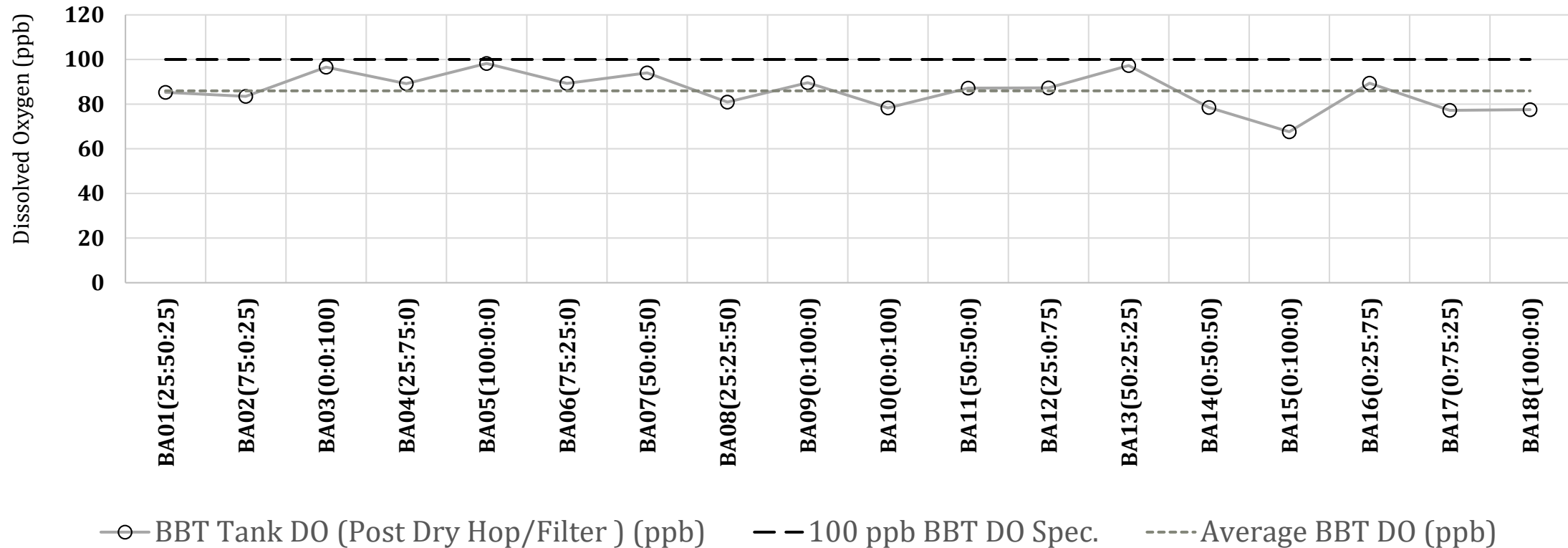


Blending & Filtration

- All dry-hop events occur in duplicate (40 L beer each)
 - Mixing pre-filtration
- During filtration 2 kegs are blended during filtration into 1 keg
 - Oxygen monitoring



Oxygen Control - Bright beer tank dissolved oxygen



- Dissolved oxygen bright beer specification limit - 100 ppb
- Average Bright Beer Tank DO ~86 ppb

Sensory Methodology

Evaluations using draft beer

- Minimized total package oxygen
- Great for sensory testing implementation



Sensory Evaluation - Descriptive Analysis

Sensory protocol

- 9 panelists
 - (8 males, 1 female; 27-54 yrs. old)
- 18 products; 15 samples and 3 controls
- 3 replications
- 4 training sessions in advance



Attributes Assessed

Overall Hop Aroma Intensity

Citrus

Herbal/Tea

Tropical Fruity

Tropical Catty

Pine/Resinous/Dank

Sensory Evaluation – Descriptive analysis external controls

<i>Attributes</i>		Unhopped base	Chinook	Centennial	Cascade	Sierra Nevada Pale Ale	Ballast Point Pineapple Sculpin	10-Barrel Joe
Assess Descriptors Based on Aroma Only	Overall Hop Aroma Intensity	0	6	9	8	7	10 - 11	14-15
	Citrus	0	2	7	8	6	6	5 - 6
	Herbal/Tea	0	3	4 - 5	6	5	2	1
	Tropical/Catty	0	4 - 5	2 - 3	3	3	4	9 - 10
	Tropical/Fruity	0-1	2 - 3	5 - 6	3	4	7 - 8	4 - 5
	Pine/Resinous/Dank	0	1	2	2	2	4	4

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Results

Internal Replications - Difference Testing

- 3 *true* replications of the dry hop process (3 DH events)
- Difference testing (triangle testing). (NSD, p -value < 0.05 , two-tail t-test)

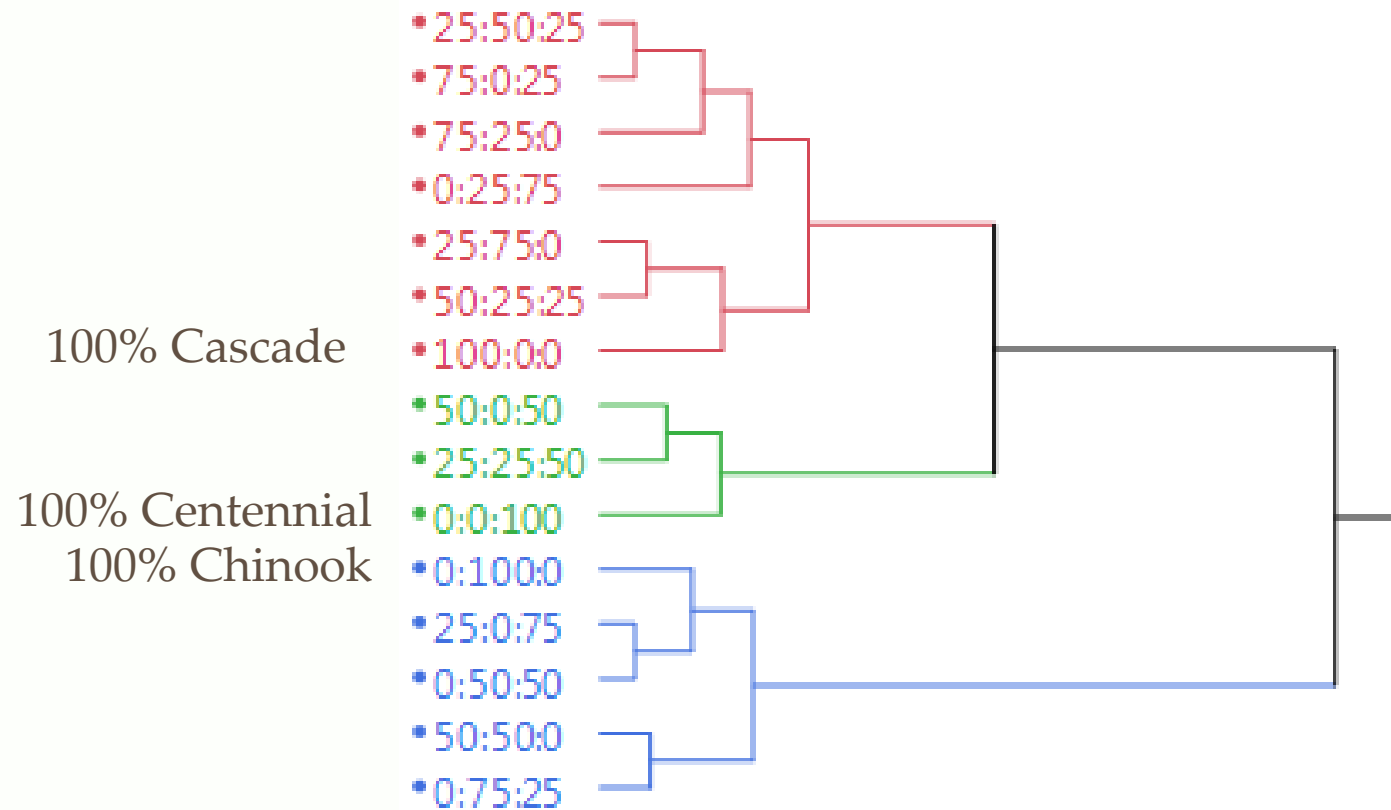


Hop Cultivar	Rep	Number of correct Responses	Total # of Participants	Z-Score	p-value (two-tail)
100% Centennial	Rep 1	13	40	-0.28	0.39
	Rep 2				
100% Chinook	Rep 1	16	40	0.73	0.23
	Rep 2				
100% Cascade	Rep 1	18	40	1.40	0.08
	Rep 2				

Hierarchical agglomerative clustering – Ward's method

Using all descriptive attributes:

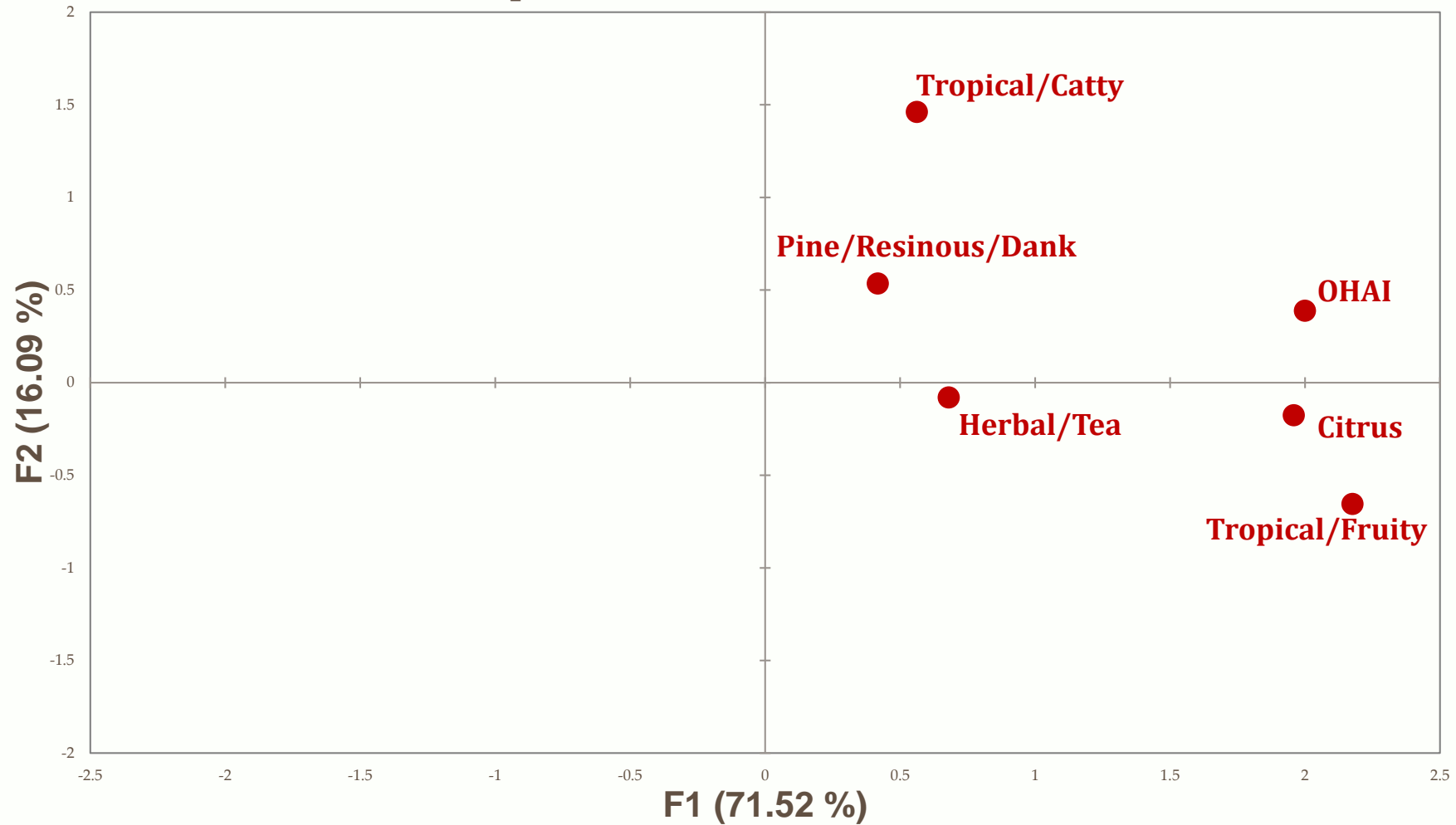
OHA1, Tropical Fruity, Tropical Catty, Citrus, Herbal/Tea, Pine/resinous/dank



% Cascade, % Chinook, % Centennial

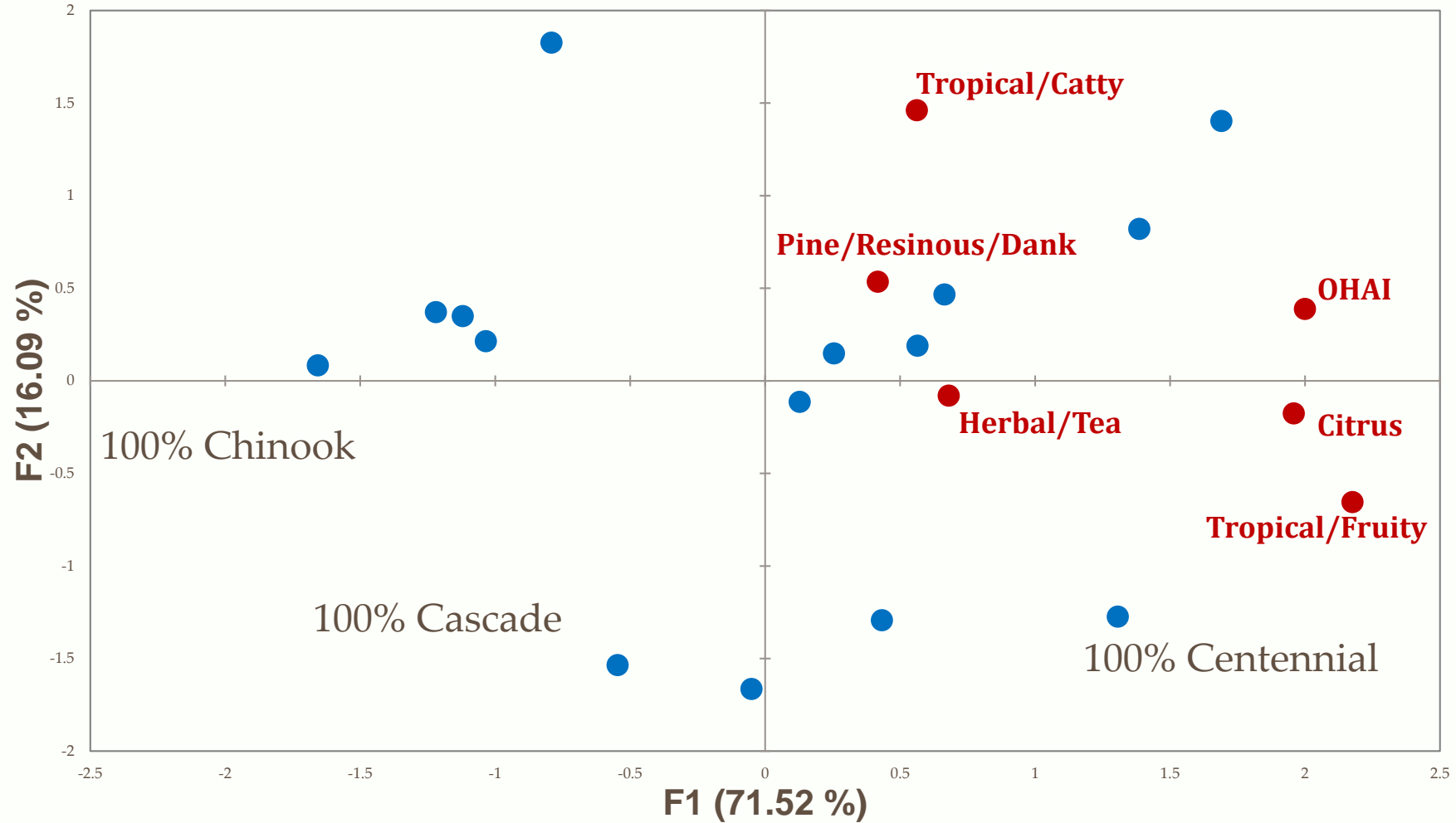
Principal Component Analysis - Covariance

Biplot (axes F1 and F2: 87.61 %)



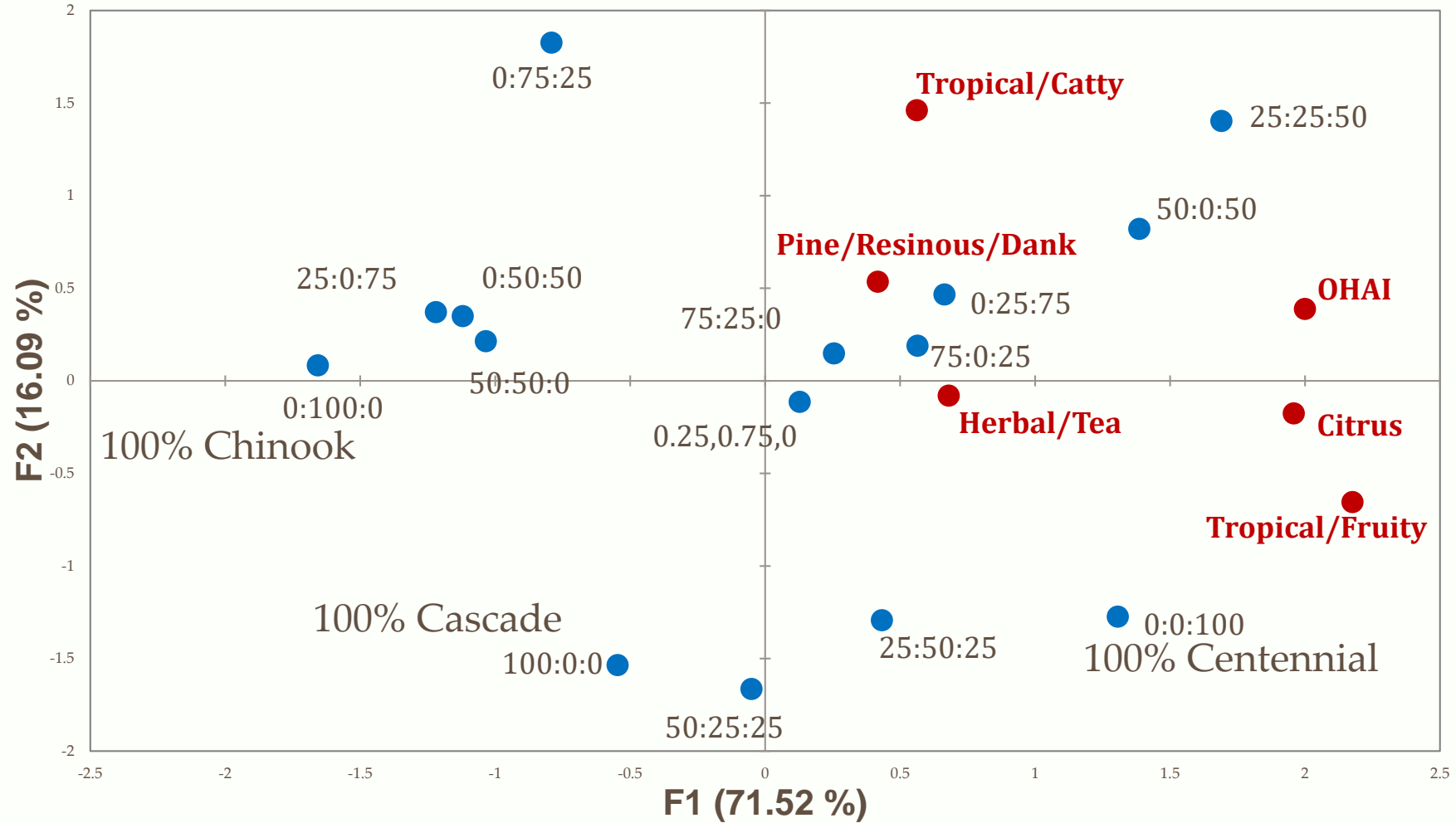
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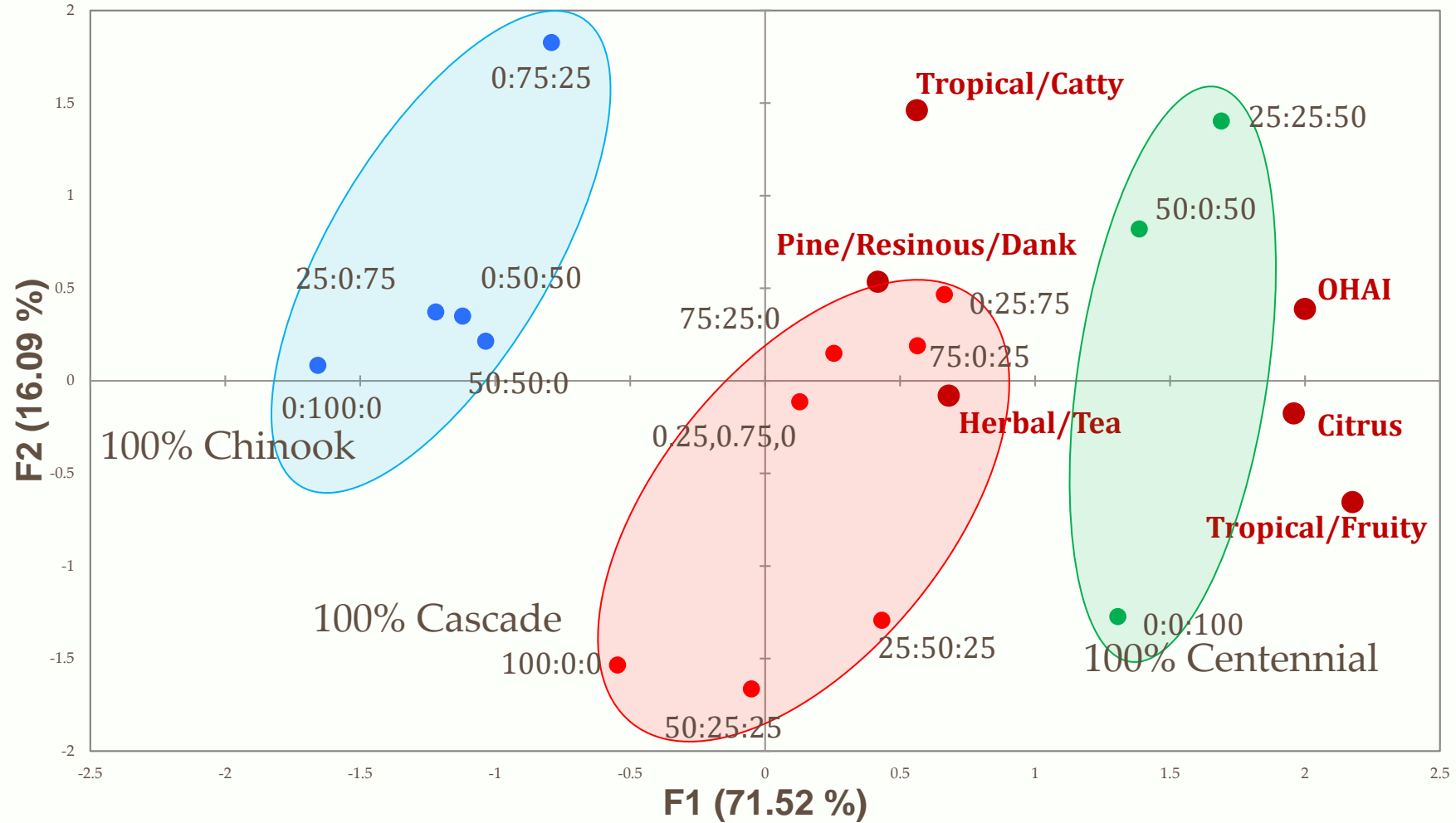
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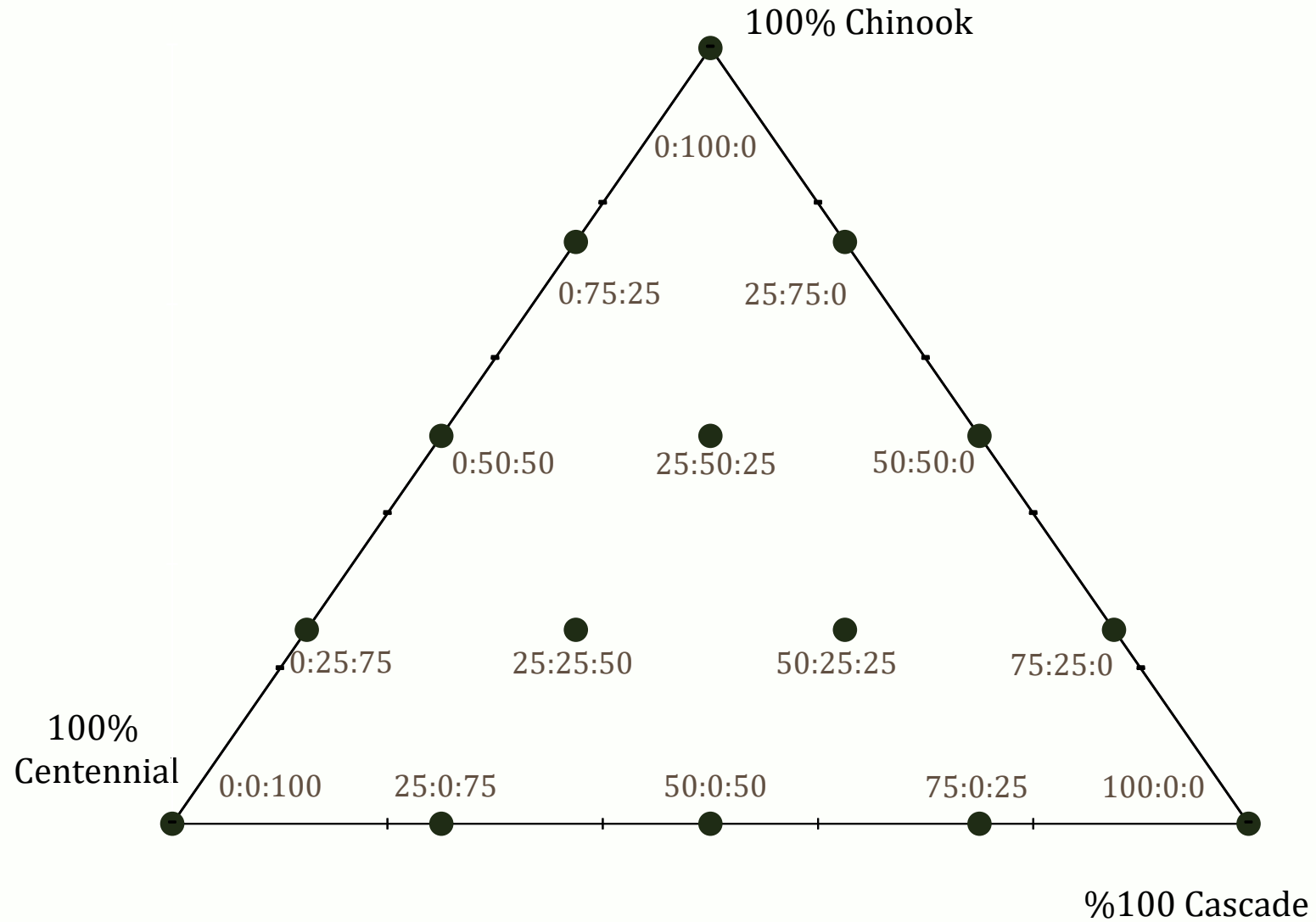
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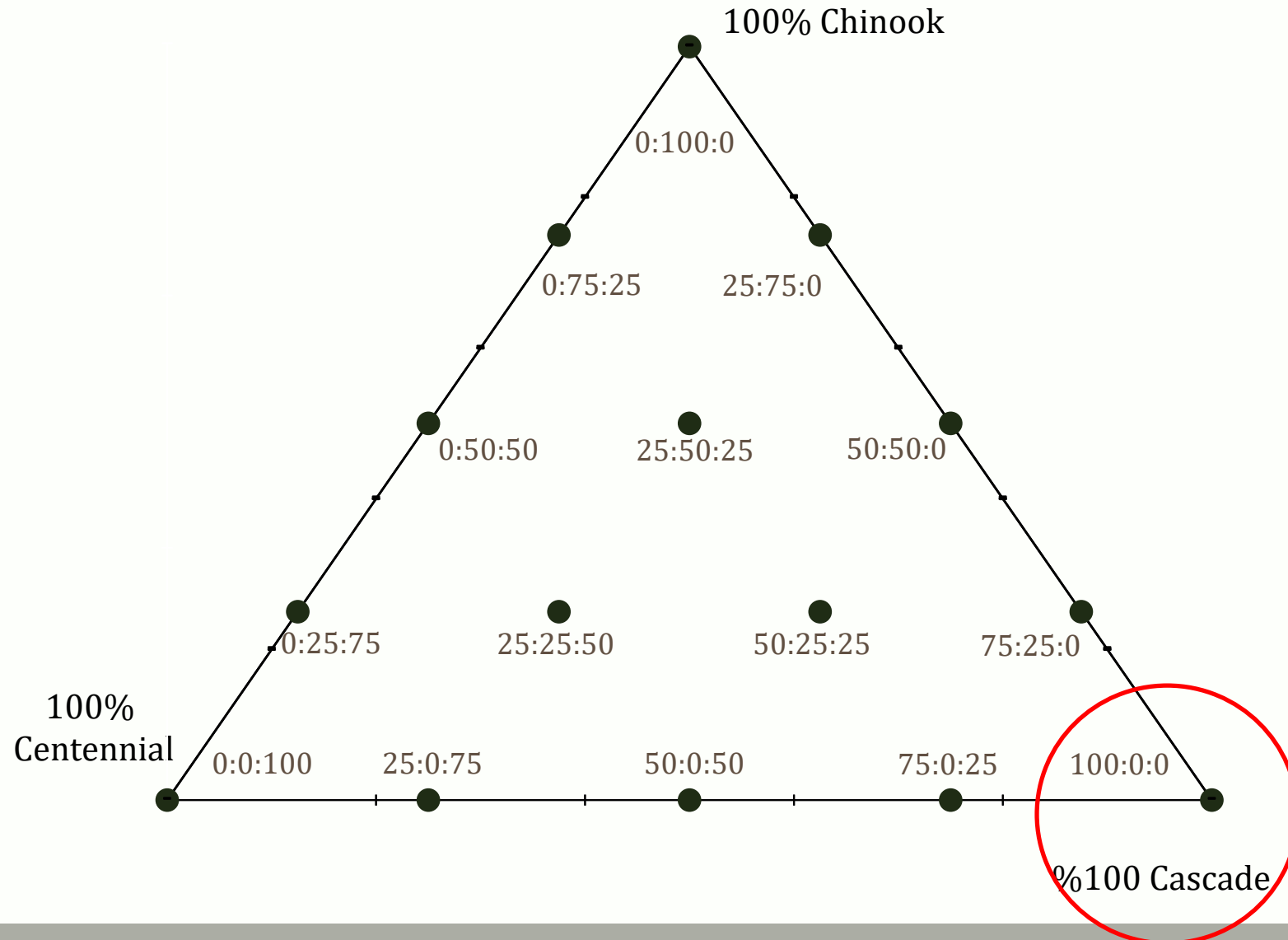


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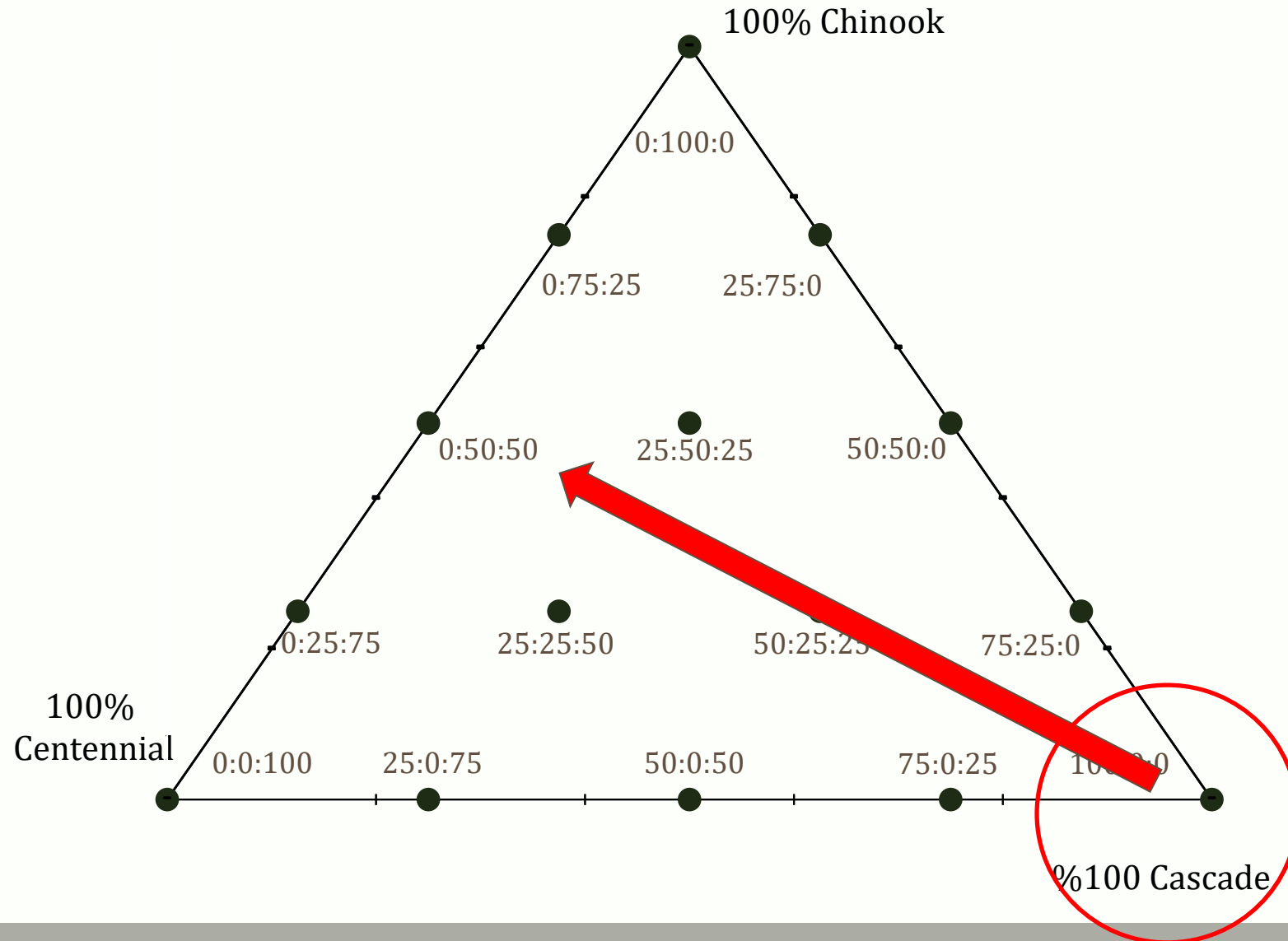
Ternary Plots - % Cascade, % Chinook, % Centennial



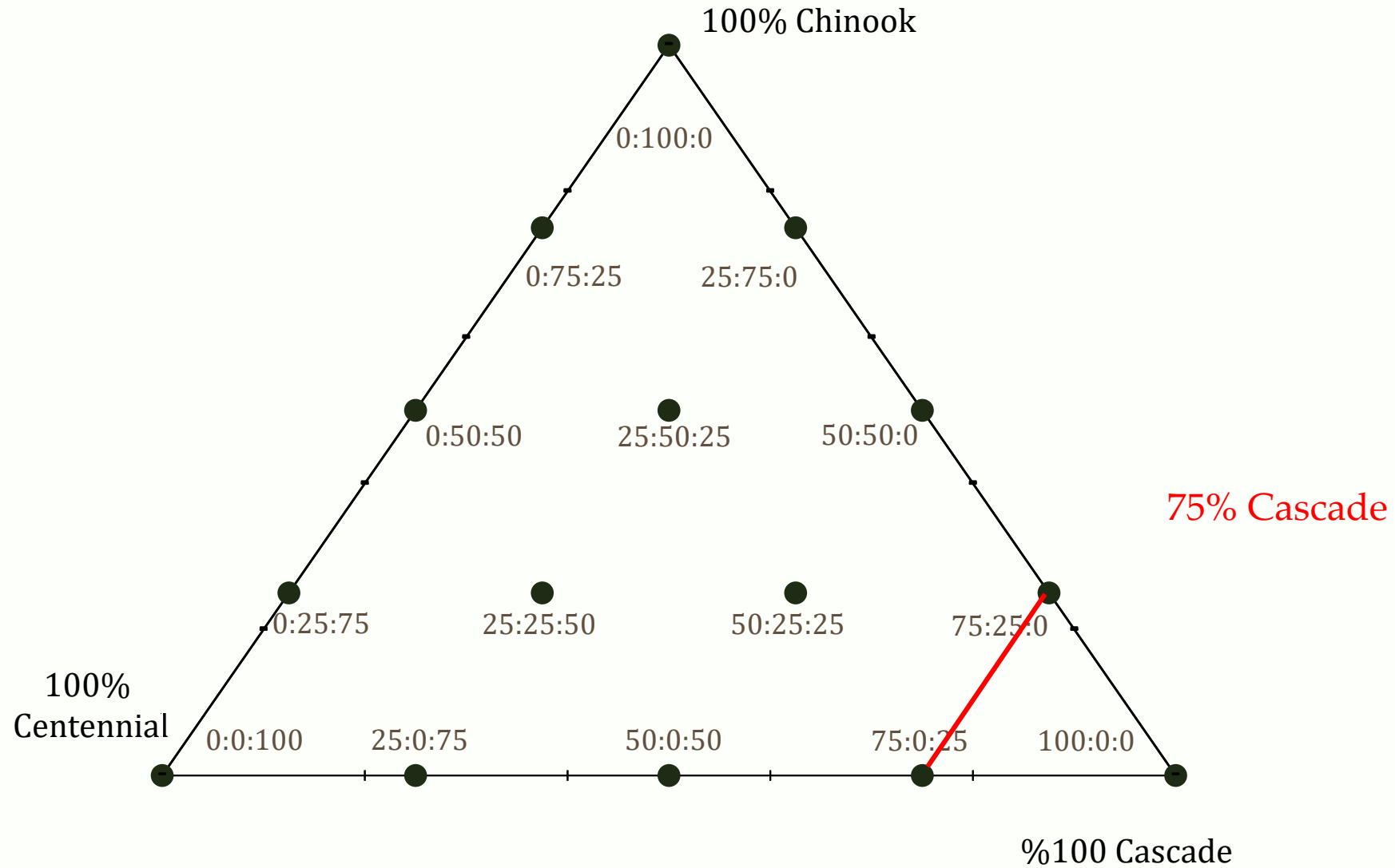
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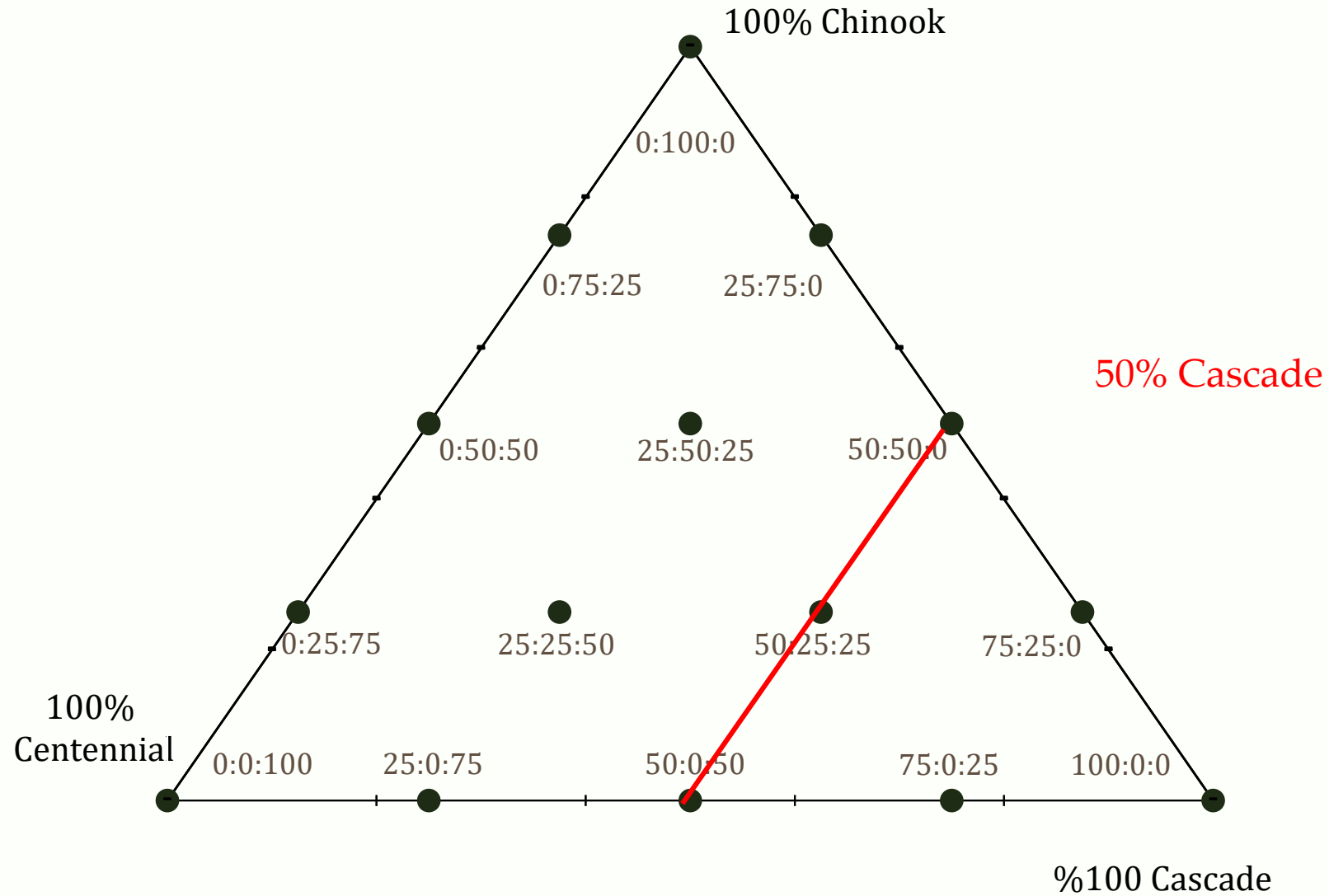
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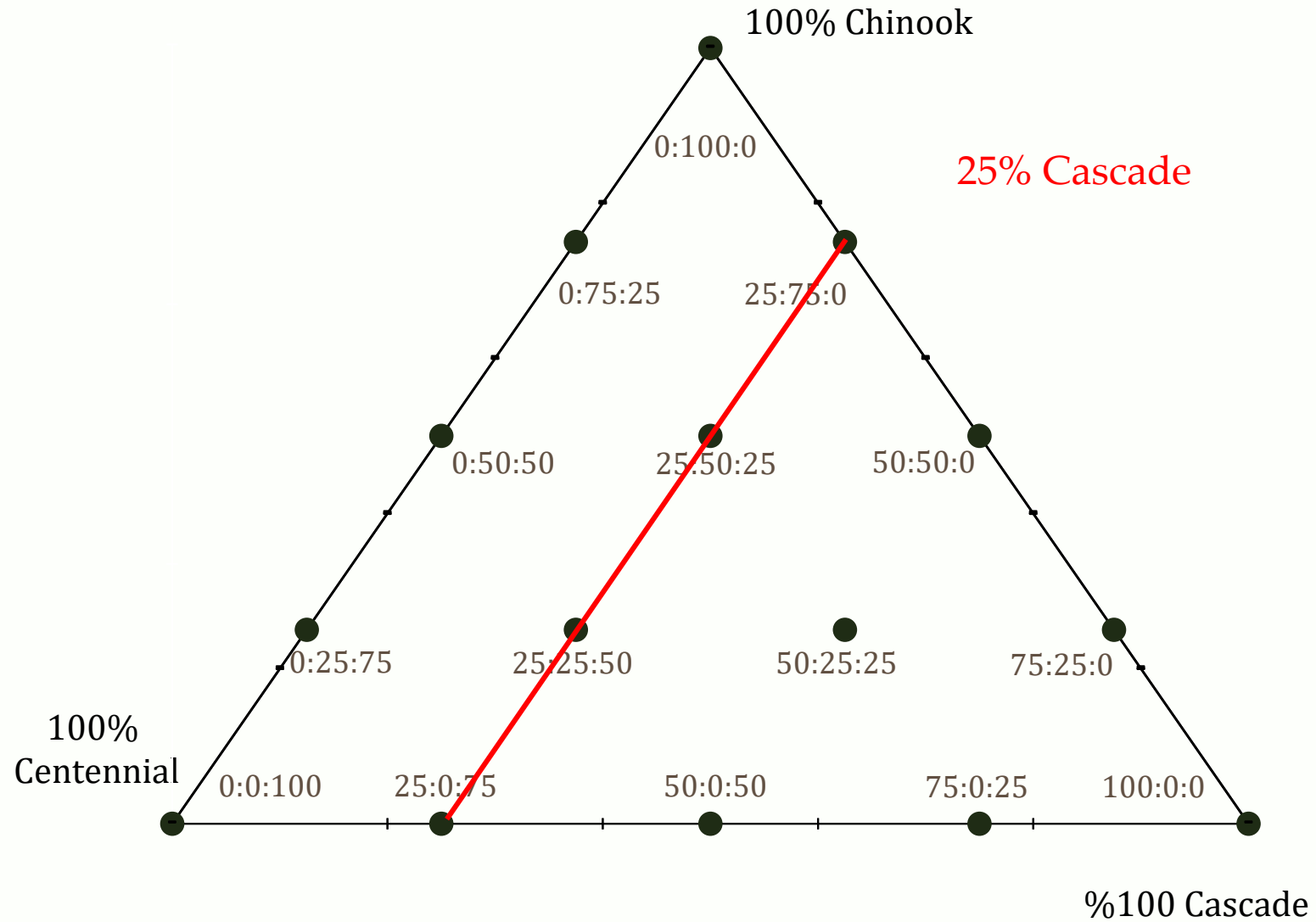
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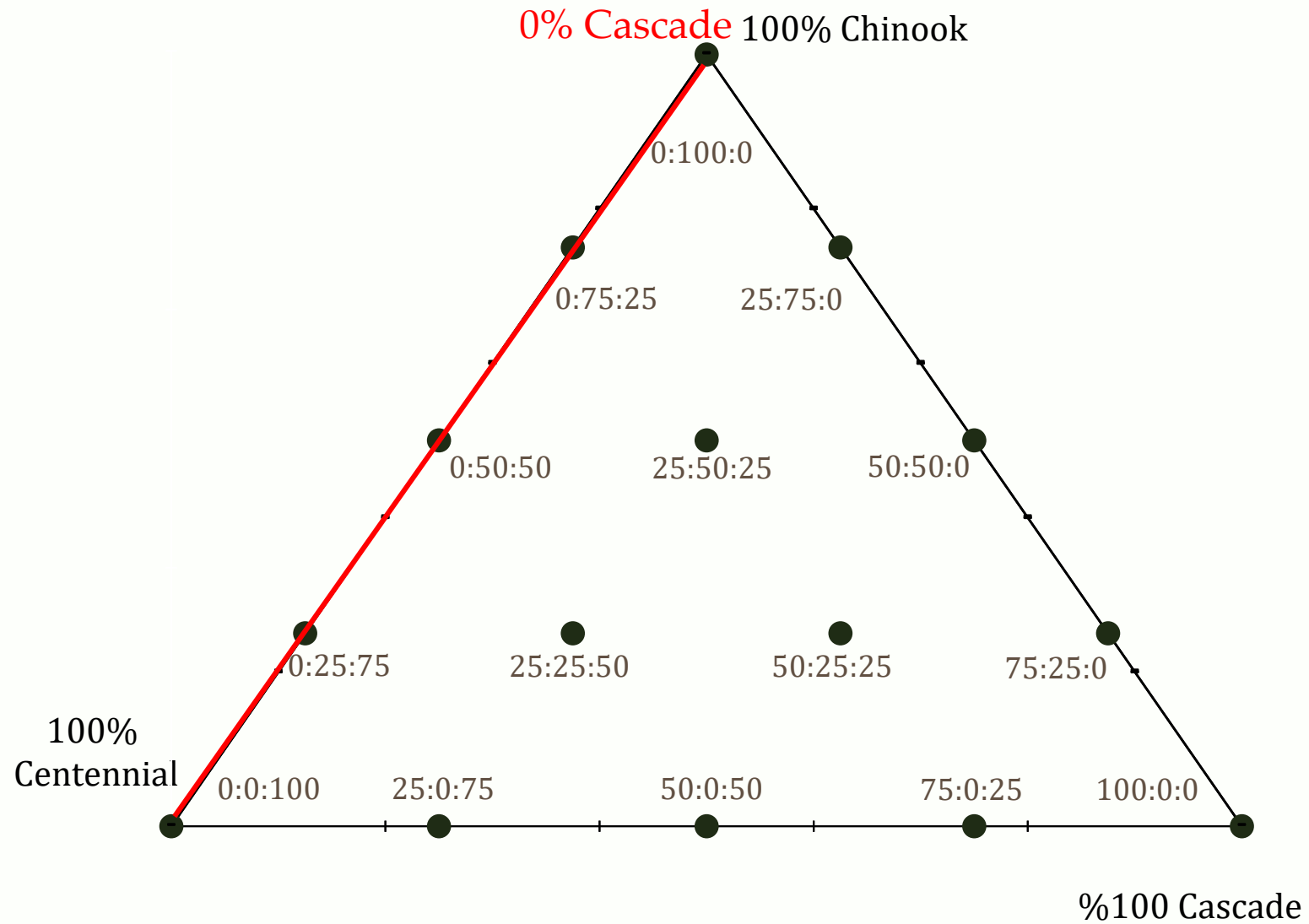
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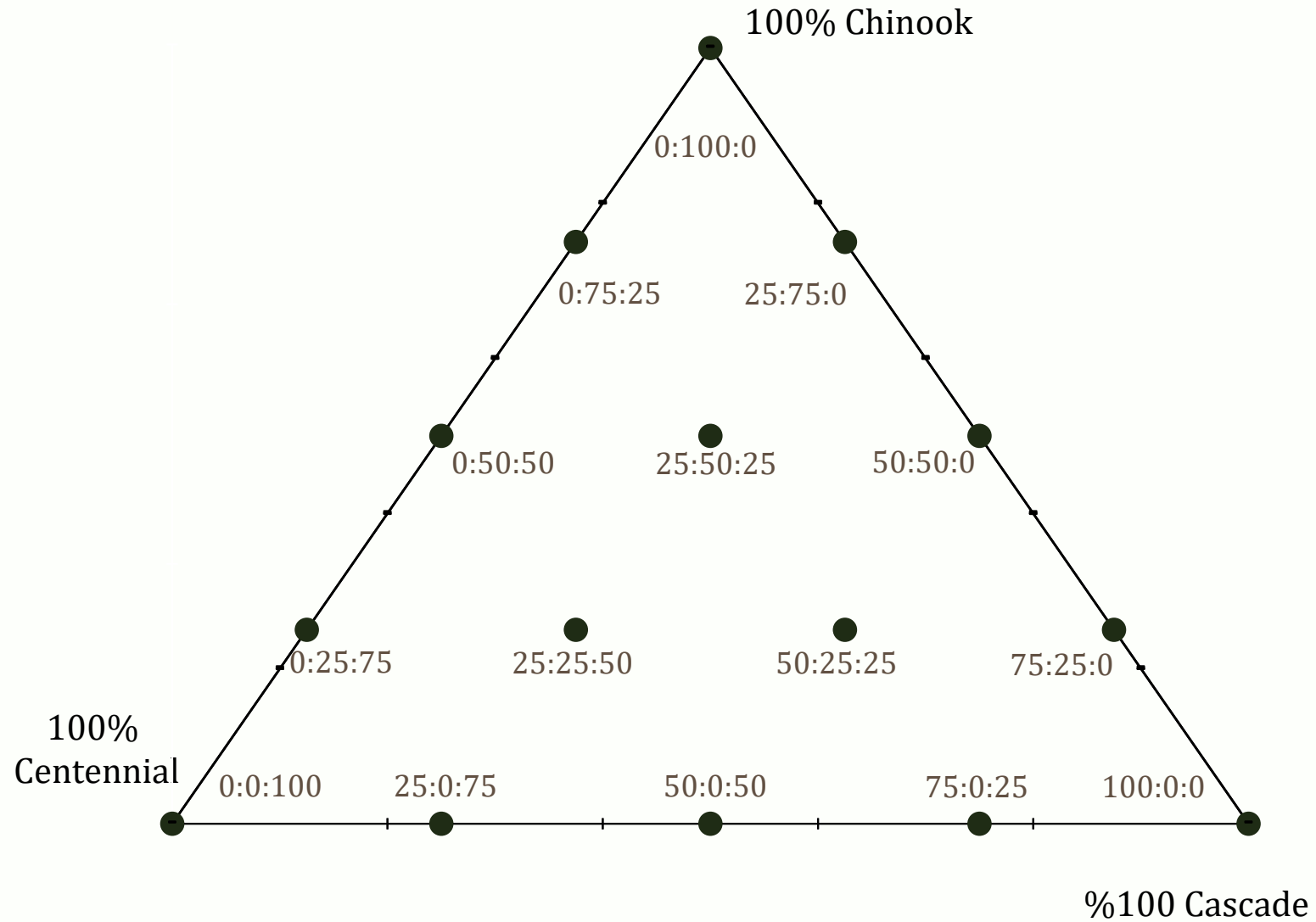
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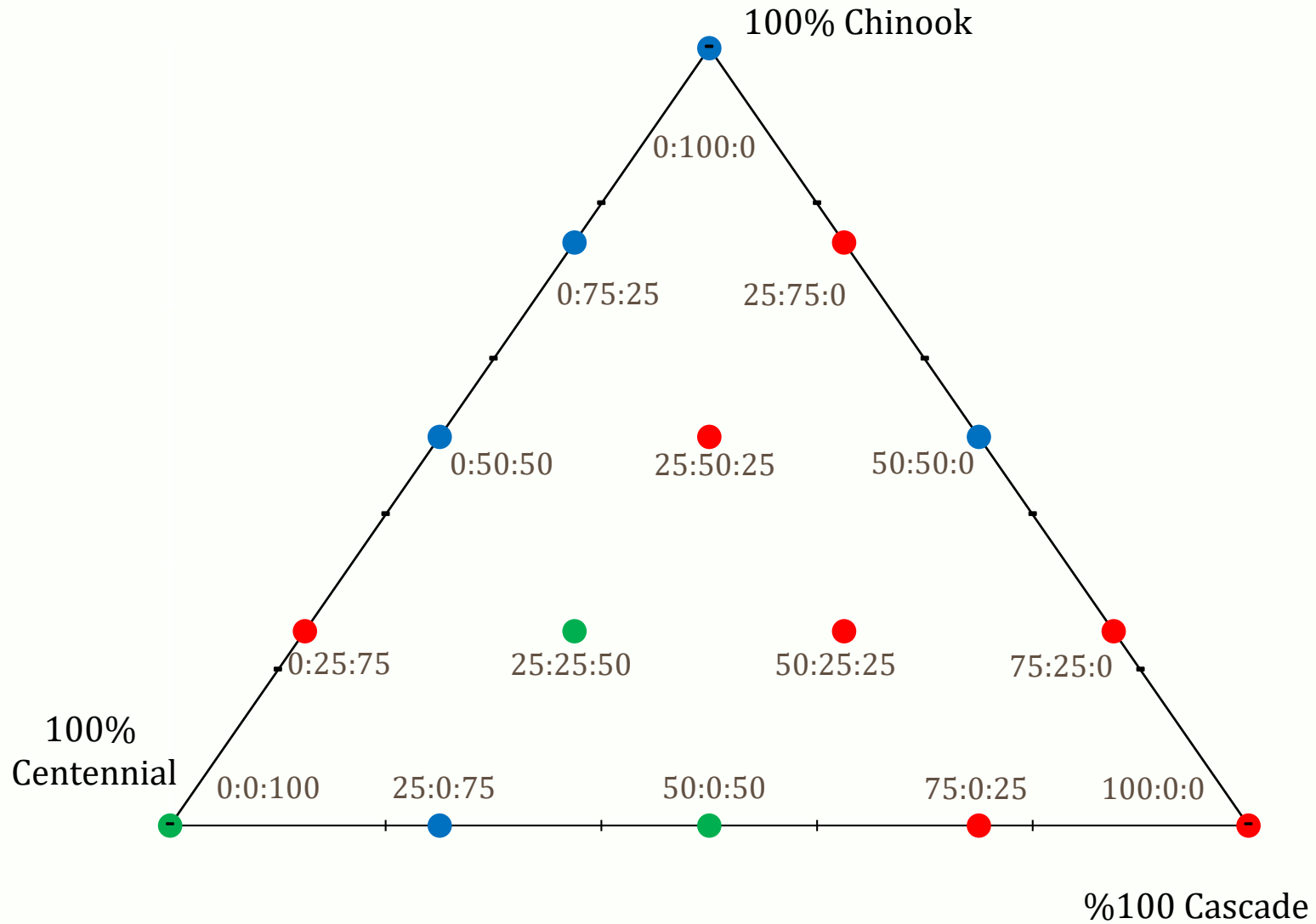
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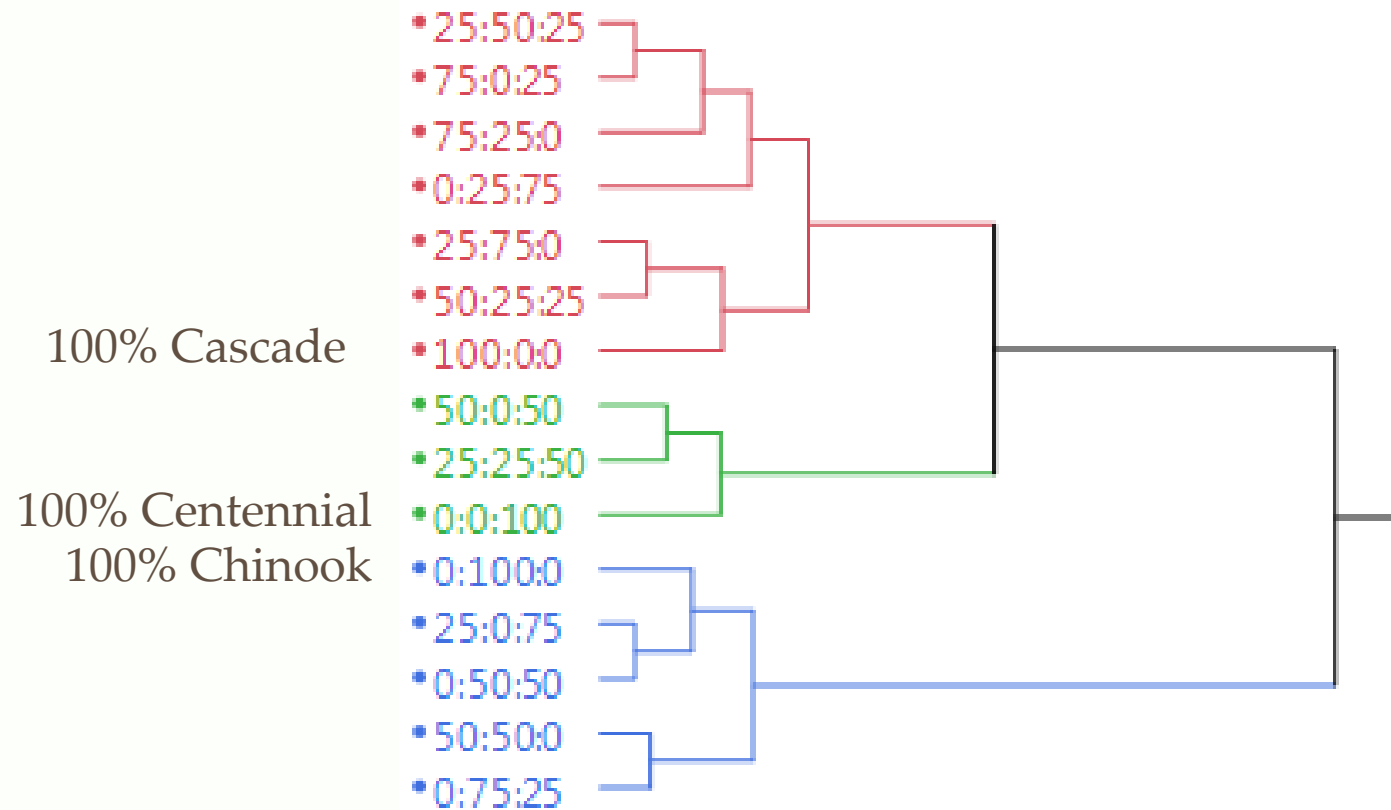
Ternary Plots – Colored by Ward Clusters



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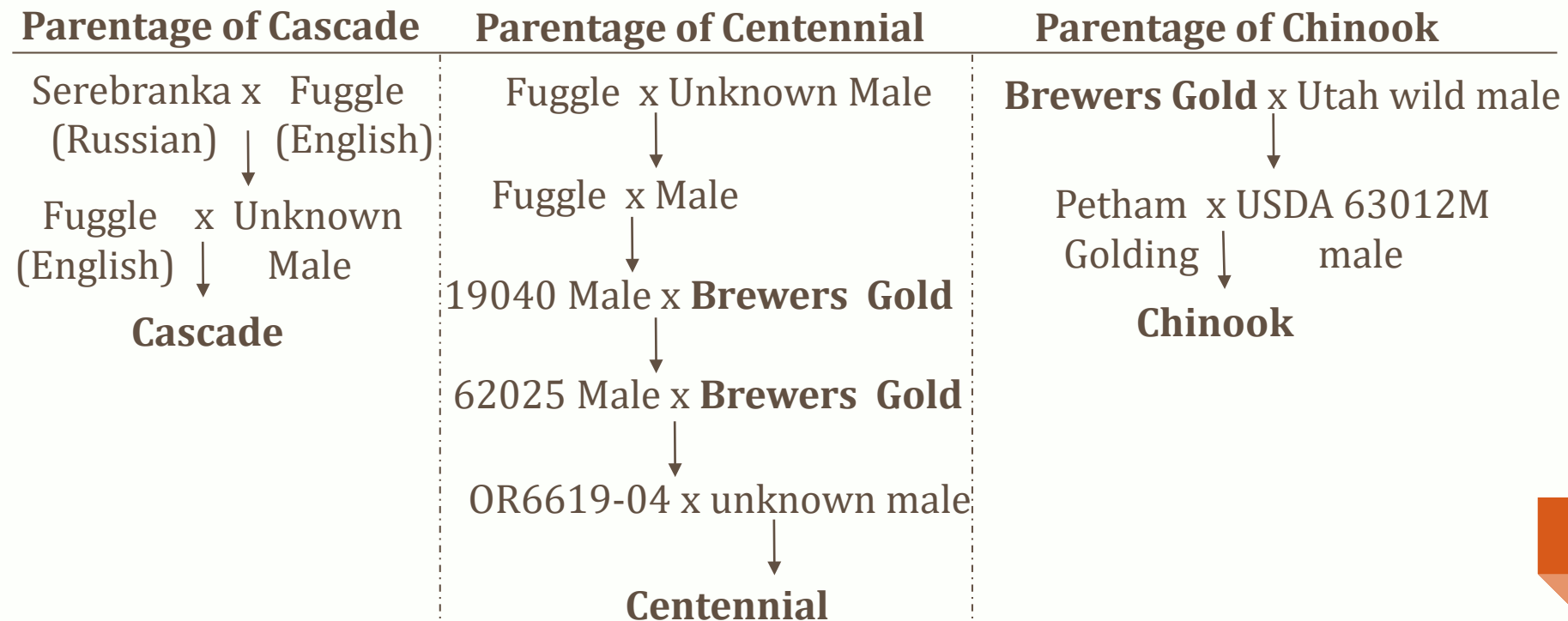
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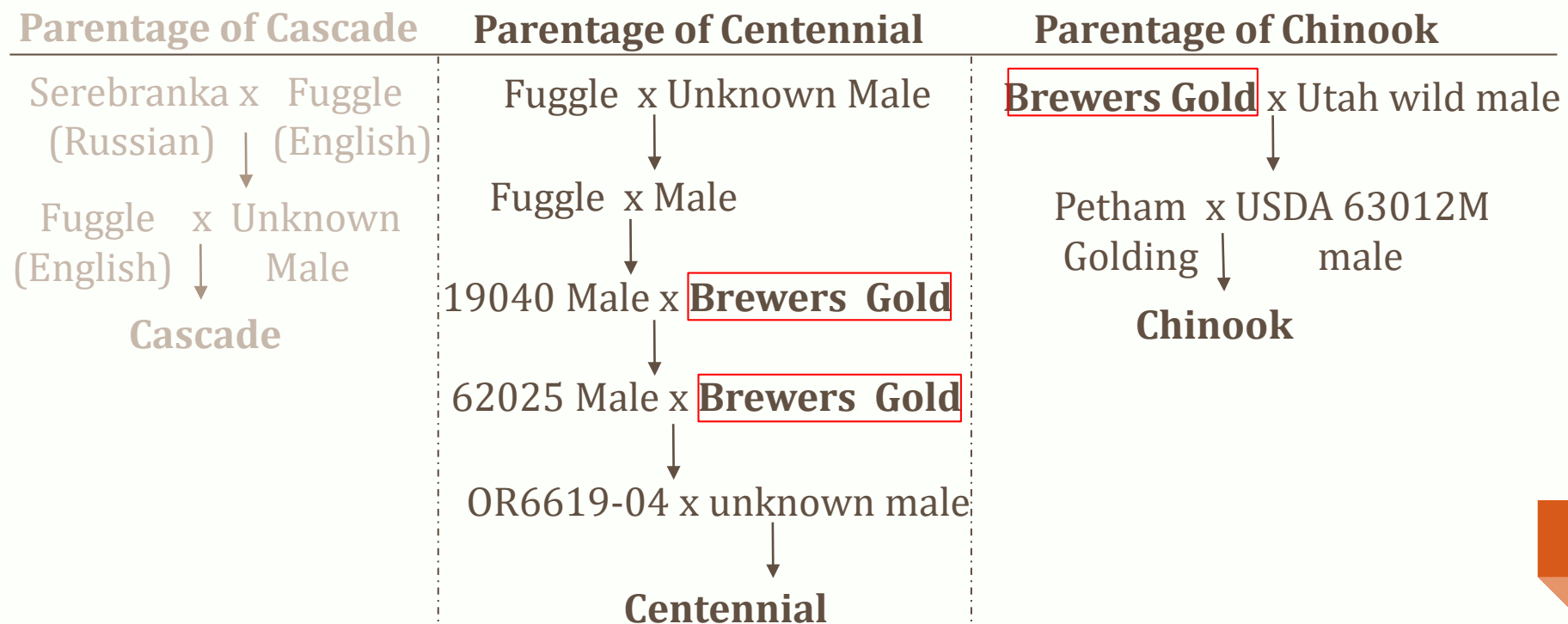
Hop cultivar pedigrees

- Possible explanation for similarities?
- Chinook and Centennial have a common ancestor in Brewers Gold
- Cascade and Centennial have common ancestor in Fuggles



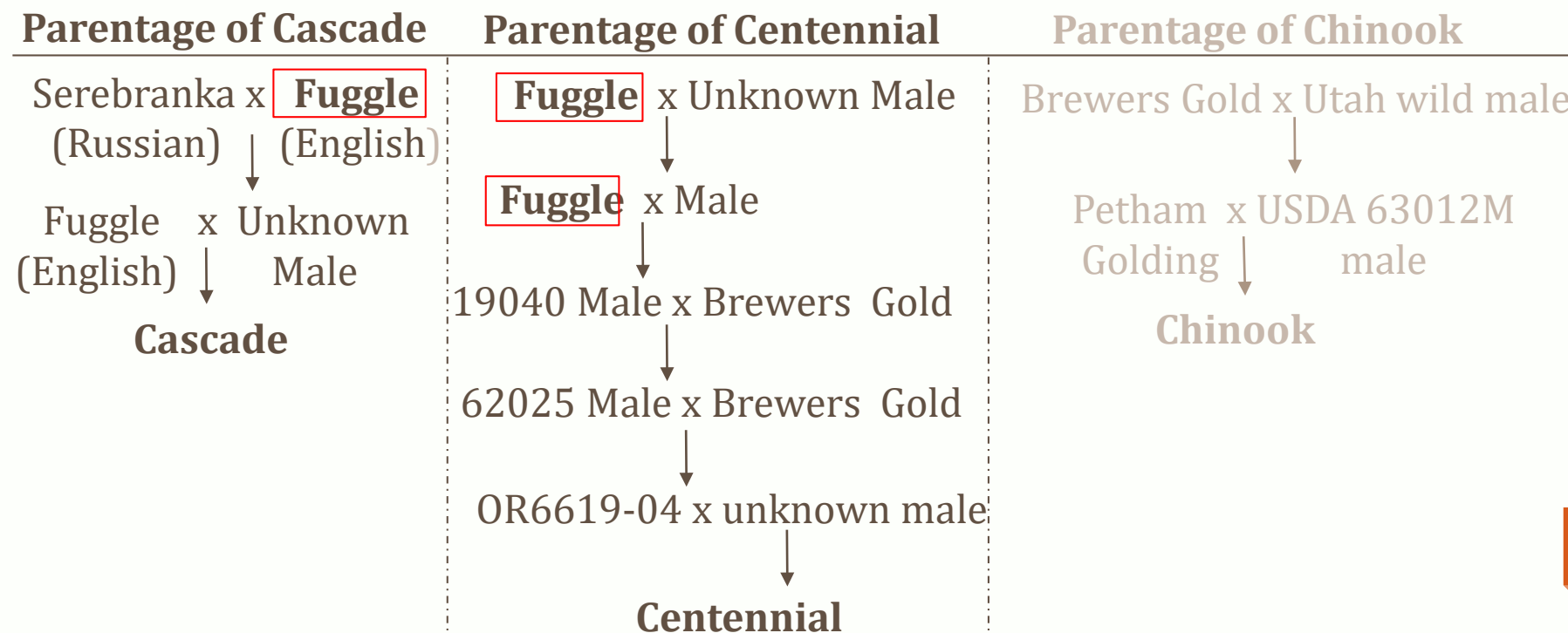
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Conclusions

- Similar overall dry-hop character/quality grouping is achievable by using hop blends

No significant differences \neq true similarity

- Hops blends produced greater dry-hop aroma intensity than single variety beers

I'd like to acknowledge...

- **Scott Lafontaine** – OSU doctoral student
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- Crosby Hop Farm
 - **Staci Wallace**
- BridgePort Brewing Company
 - **Jeff Edgerton and Christian Engstorm**

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