Measurement of Bleaching Yield by Carbohydrate Analysis

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Yield Measurement by Carbohydrate Analysis

- Use of cellulose yield as a basis for pulp yield measurement first proposed by Rydholm (1970)
- Method further developed by Easty and Malcolm [Tappi J. **65**(12): 78-80 (1982)]
- Use for pulping yield measurement is based on the observation that yield of cellulose in kraft pulping is constant after the initial phase
- Cellulose yield must be determined by species

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Pulping Yield Measurement by Carbohydrate Analysis

Bleaching Yield =

$$\frac{g\,cellulose}{100\,g\,wood} \Big/ \frac{g\,cellulose}{g\,pulp} =$$

$$\left(\frac{g\,cellulose}{100\,g\,wood}\right) \bullet \left(\frac{g\,pulp}{g\,cellulose}\right) = \left(\frac{g\,pulp}{100\,g\,wood}\right)$$

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Nomenclature

Y_{cell} = yield of cellulose, assumed to be constant after the initial phase of kraft pulping (36.0% for loblolly pine)

- C = weight fraction cellulose in pulp
- H = weight fraction lignin in pulp
- L = weight fraction lignin in pulp
- O = weight fraction other components in pulp

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Pulping Yield Measurement by Carbohydrate Analysis

Bleaching Yield =

$$\left(\frac{g\,cellulose}{100\,g\,wood}\right)\bullet\left(\frac{g\,pulp}{g\,cellulose}\right)=$$

$$Y_{cell}\bullet\left(\frac{C+H+L+O}{C}\right)$$

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Pulping Yield Measurement by Carbohydrate Analysis

Bleaching Yield =

$$Y_{cell} \bullet \left(\frac{C + H + L + O}{C} \right) \approx$$

$$Y_{cell} \bullet \left(\frac{C + H}{C} \right) + Y_{cell} \bullet \left(\frac{L}{C} \right)$$

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Lignin-Carbohydrate Method vs. Cellulose Method

Cellulose content of pulp is subject to analytical errors that will affect yield estimates calculated directly from cellulose content

- This difficulty is gotten around by using the second form of the equation on the previous slide to calculate yield from the ratio (C + H)/C, in which the errors in C in the numerator and denominator compensate

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Pulping Yield Measurement Assumptions

- Y_{cell}, the yield of cellulose, is constant over the range of degrees of delignification for which yield estimates are desired
- The yields of pulp components other than cellulose, hemicellulose and lignin are negligible in comparison to the yields of these major components

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Bleaching Yield Measurement by Carbohydrate Analysis

Bleaching Yield =

$$\frac{g\,cellulose}{100\,g\,u.pulp} \Big/ \frac{g\,cellulose}{g\,b.pulp} =$$

$$\left(\frac{g\,cellulose}{100\,g\,u.pulp}\right) \bullet \left(\frac{g\,b.pulp}{g\,cellulose}\right) = \left(\frac{g\,b.pulp}{100\,g\,u.p.}\right)$$

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Bleaching Yield Measurement by Carbohydrate Analysis

Bleaching Yield = :

$$\left(\frac{g\,cellulose}{100\,g\,u.\,pulp}\right)\bullet\left(\frac{g\,b.\,pulp}{g\,cellulose}\right)=$$

$$\left(\frac{100\bullet C}{C+H+L+O}\right)_u\bullet\left(\frac{C+H+L+O}{C}\right)_b$$

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Bleaching Yield Measurement by Carbohydrate Analysis

Bleaching Yield =

$$\left(\frac{100 \bullet C}{C+H+L+O}\right)_u \bullet \left(\frac{C+H+L+O}{C}\right)_b =$$

$$100 \bullet C_u \bullet \left(\frac{C+H}{C}\right)_b$$

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Bleaching Yield Measurement by Carbohydrate Analysis

$$C_u = \left(\frac{C}{C + H + L + O} \right)_u =$$

$$\left(\frac{C}{C + H} \right)_u \bullet \left(\frac{C + H}{C + H + L + O} \right)_u =$$

$$\left(\frac{C}{C + H} \right)_u \bullet (1 - L - O)_u$$

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Bleaching Yield Measurement by Carbohydrate Analysis Final Equation

Bleaching Yield =

$$100 \bullet \left(\frac{C}{C+H}\right)_u \bullet (1 - L - A - E)_u \bullet \left(\frac{C+H}{C}\right)_b$$

in which A and E are wt. fractions of ash and extractives

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Bleaching Yield Measurement Assumptions

- No cellulose is lost during bleaching
- Bleached pulp contains only cellulose and hemicellulose
- Unbleached pulp contains only cellulose, hemicellulose, lignin, ash and extractives

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Example of Data Needed for Bleaching Yield Estimation

	Unbleached	Bleached
Components, % o.d.p.		
Total Carbohydrates	96.4	101.0
Cellulose	79.4	83.7
Lignin	2.3	-
Ash	0.4	-
Extractives	0.1	-
Cellulose, % of total carbohydrates	82.4	82.9

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Sample Calculation of Bleaching Yield

Bleaching Yield =

$$100 \bullet \left(\frac{C}{C+H}\right)_u \bullet (1-L-A-E)_u \bullet \left(\frac{C+H}{C}\right)_b =$$

$$\frac{100 \bullet 0.824 \bullet (1-.0023-.004-.001)}{.829} = 96.6\%$$

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Conclusions

- Carbohydrate analysis, previously shown to be useful for estimating digester yields, is even more applicable to the estimation of yield losses-shrinkage in bleaching.
- The necessary assumptions concerning the compositions of the pulp before and after bleaching and cellulose stability during bleaching appear reasonable.

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Conclusions

- Application of the method in the laboratory to several different pulps has given yield estimates which are consistent with experience in every case.
- The method will be particularly useful for monitoring yield loss in mills, either during routine operation or during mill experiments.

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