OC Curves in QC Applied to Sampling for Mycotoxins in Coffee

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Motivation

• Shipping grain to a consumer carries a risk
  – The cargo is shipped assuming that it meets the consumer specifications (multiple quality parameters)
  – Sampling at loading determines whether the cargo is dispatched
  – Sampling at receipt determines acceptance of the cargo

• Risks to the shipper and receiver can be quantified by an OC or ‘operational characteristic’ curve

• The OC curve is a general tool of quality control that seems to have been ignored by sampling folk
OC Curves

• What is an OC curve?
  – The OC curve provides the probability that a lot of material will be accepted as a function of the TRUE value of the assay.

• Two pieces of information are needed to construct the OC curve:
  – The distribution of the measurement uncertainty
  – The acceptance criterion
OC Curves

- Example
  - Coal ash content is determined with an SD of 0.1% ash and the uncertainty is normally distributed.
  - What is the risk of buying a shipment of coal having a true ash content of 10.15% when the acceptance criterion is <=10.00% ash?

6.68%
OC Curves

• Example

– We can also look at the sellers risk. If he supplies coal at 9.9% ash, the probability that the buyer will accept the coal is 84.1% so the probability that the coal will be *incorrectly* rejected is $100 - 84.1 = 15.9\%$.
OC Curves

• Reducing Risk
  – Make the analysis more accurate
  – Change the acceptance criterion

• Both these alternatives are costly
  – The seller will ask a higher price for the cleaner coal
  – More accurate analysis may require better sampling equipment or more replicate analyses
Application to Coffee Sampling for OTA

• OTA (Ochratoxin A) is a mycotoxin produced by moulds that grow on many kinds of foodstuffs (Durum wheat, coffee, dried fruits, grapes, maize, barley ...)

• It can be present in extremely high concentrations on a single kernel of wheat or coffee bean (10^5 ppb)

• The allowable level in a lot is 5 ppb

• The lot can therefore be extremely heterogeneous with respect to OTA — difficult sampling
Application to Coffee Sampling for OTA

*Penicillium verrucosum* on wheat
Application to Coffee Sampling for OTA

• To apply the OC curve method to coffee sampling, it is not sufficient to determine the sampling variance:
  
THE FULL DISTRIBUTION OF THE UNCERTAINTY MUST BE KNOWN

• Further, the distribution usually changes with the level of contamination

• The work required is substantial
Coffee Sampling

- Whitakers design for OC curve development
Coffee Sampling

• Determination of assay distribution shape

For each of the 25 samples, the empirical distribution function is plotted and fitted by a distribution. One family of distributions is used for all 25 fits.
Coffee Sampling

• Replication permits estimation of:
  – total variance
  – ‘preparation’ variance
  – analysis variance
  – subtract prep and analysis variance from total to get ‘sampling’ variance

• At each of 25 concentrations

• For each variance component, regress variance against concentration
Coffee Sampling

• The total variance was modelled by a log-normal distribution (2 parameters: mean and variance)

• By specifying an acceptance level, an OC curve can be calculated
  – it all looks nice and neat and complete

However, there is an important flaw in this experimental plan
The Flaw

• The procedure fails to account for the distributional heterogeneity of the coffee that exists between and within sacks, or truckloads

• A lot of coffee consisting of say 500 sacks is far from homogeneous and there will be a substantial variance component associated with sampling from the sacks

• This component is probably the largest component of all!
Conclusion

• OC curves are a very useful tool for quantifying risk
• They must be constructed taking ALL sources of variance into account
• They bring a new discipline to sampling in that they demand discovery of the full distribution of uncertainty in sampling and analysis