Why do we have so many different types of sampling plans ?

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Product testing

Outbreak: new microbiological criteria:

close the well after the calf has drowned

(shutting the stable door after the horse has bolted)

Testing is not very effective in detecting contaminants

- lottery effect
- local contaminations
- methods not perfect

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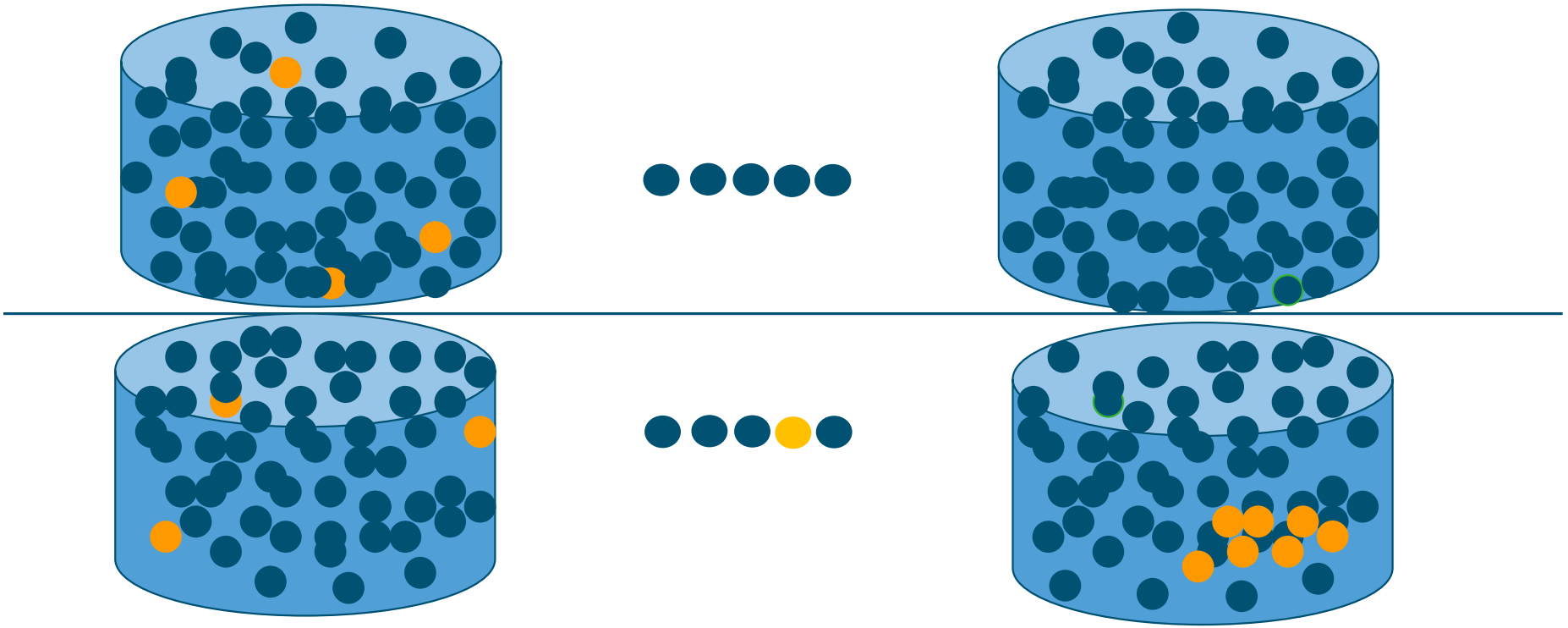
End product testing useful or lottery ?



If the tested sample units are negative, this does not mean the batch is free of the pathogen

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Only a very minor proportion of product is sampled

Salmonella in poultry in the EC: 50 samples per slaughterhouse in 10 weeks: 0.0022% of the carcasses !

Cronobacter in PIF 30 samples of 10g per batch =0.3 kg / 20,000 kg = 0.0014%

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Sampling and testing for pathogens in food: finding the needle in a haystack and the impact of the food microbiome. Heidy MW den Besten, Johanna Mentani and Marcel H Zwietering. https://doi.org/10.1016/j.cofs.2025.101332
Actual distribution of *Cronobacter* spp. in industrial batches of powdered infant formula and consequences for performance of sampling strategies. I. Jongenburger, M.W. Reij, E.P.J. Boer, L.G.M. Gorris, M.H. Zwietering. https://doi:10.1016/j.ijfoodmicro.2011.08.003

Testing is not the basis of food safety

Verification by MicroCrit

Monitor Critical Limits

Validated CCPs

HACCP

PRP (GMP, GHP, ...)

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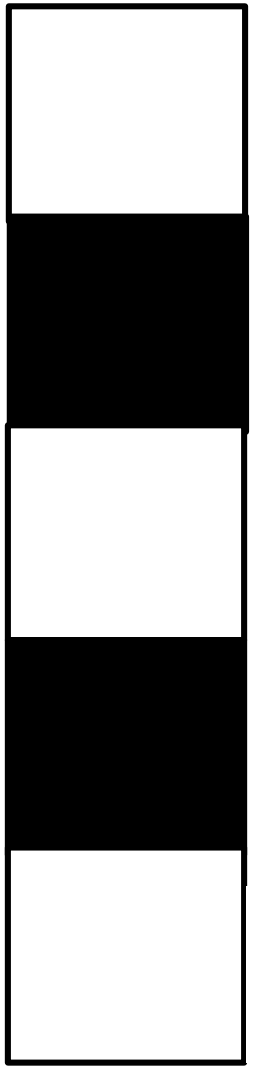
Only testing is not solid

verification
by MicroCrit

Why different types: it is not black and white



indicators / hygiene indicators

toxigenic organisms / infective organisms

target group: general population, infants, medicinal food

potential after sampling point (inactivation, stable, growth)

50 shades of red

Total Plate Count

Mesophiles

Enterobacteriaceae

Bacillus cereus

Campylobacter in raw poultry

Salmonella in raw poultry

Salmonella in RTE food

Salmonella in PIF

(Hygiene) Indicators

Inactivation after sampling point

Target group: infants

RTE= Ready to Eat PIF = Powdered Infant Formula

ICMSF Table of 15 cases

	Likely change before consumption		
Category	Reduce	No Change	Increase
Utility	Case 1: n=5, =3	Case 2: n=5, c=2	Case 3: n=5, c=1
Indicator	Case 4: n=5, c=3	Case 5: n=5, c=2	Case 6: n=5, c=1
Moderate	Case 7: n=5, c=2	Case 8: n=5, c=1	Case 9: n=10, c=1
Serious	Case 10: n=5, c=0	Case 11: n=10, c=0	Case 12: n=20, c=0
Severe	Case 13: n=15, c=0	Case 14: n=30, c=0	Case 15: n=60, c=0

3 Class sampling plan

2 Class sampling plan

Types of sampling plans

Qualitative	Quantitative
2-class	3-class
Food Safety Criteria	Process Hygiene Criteria

Qualitative: +/-: 0/25g

Quantitative: ≤ 100 cfu/g or >100 cfu/g

2-class: +/- or x≤100 cfu/g ; x>100 cfu/g

3-class: x<500 /g; 500<x≤5000; x>5000/g

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cfu = colony forming units

Types of sampling plans

Qual/Quant	Qual	Quant	Quant
Class	2	2	3
Example	*Salmonella* in PIF	*Listeria* in no growth RTE	Mesophiles in PIF

Food Safety Criterion
Process Hygiene Criterion

Sampling plan: Food Safety Criterion

Food category: powdered infant formulae (PIF)

Microorganism	Sampling plan		Sample weight (g)	Analytical method
	n	*c*		
Salmonella	60	0	25	ISO 6579

CODEX Code of hygienic practice for powdered formulae for infants and young children CAC/RCP 66-2008

Qualitative, 2-class, *c*=0

Is there one or more *Salmonella* (detected) in my 25 g

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Sampling plan: Process Hygiene Criterion

Food category: powdered infant formulae (PIF)

Micro-organism	Sampling plan		*m*	*M*	Analytical method
	n	*c*			
Enterobacteriaceae	10	2	0/10 g	-	ISO 21528-1/21528-2

CODEX Code of hygienic practice for powdered formulae for infants and young children CAC/RCP 66-2008

Qualitative, 2-class, $c \neq 0$

Is there one or more enteros (detected) in my 10 g

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Sampling plan: Food Safety Criterion

Ready-to-eat foods, not supporting growth, from end of manufacture or port of entry, to the point of sale

Micro-organism	Sampling plan		*m*	*M*	Analytical method
	n	*c*			
Listeria monocytogenes	5	0	100 cfu/g	-	ISO 11290-2

CODEX Guidelines on the application of general principles of food hygiene to the control of *Listeria monocytogenes* in foods. CAC/GL 61 - 2007

Quantitative, 2-class, *c*=0

>100 cfu/g of *Listeria* in my sample ?

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Sampling plan: Process Hygiene Criterion

Campylobacter on broilers

Micro-organism	Sampling plan		*m*	*M*	Analytical method
	n	*c*			
Campylobacter spp.	50	10*	1000 cfu/g	-	ISO 10272-2

* *c*-value increased stringency: 2018: *c*=20; 2020: *c*=15; 2025: *c*=10
EC regulation 2073/2005

Quantitative, 2-class, $c \neq 0$

are there >1000 cfu/g of *Campylobacter* in my sample

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Sampling plan: Process Hygiene Criterion

Food category: powdered infant formulae (PIF)

Micro-organism	Sampling plan		*m*	*M*	Analytical method
	n	*c*			
Mesophiles	5	2	500/g	5000/g	ISO 4833

CODEX Code of hygienic practice for powdered formulae for infants and young children CAC/RCP 66-2008

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Quantitative, 3-class, $c \neq 0$

Sampling plan: Food Safety Criterion

Potential criterion for *Listeria monocytogenes* in RTE food*

Micro-organism	Sampling plan		*m*	*M*	Analytical method
	n	*c*			
Listeria monocytogenes	5	1	0/25 g	100 cfu/g	ISO 11290-1 ISO 11290-2

3-class, $c \neq 0$, qualitative and a quantitative limit

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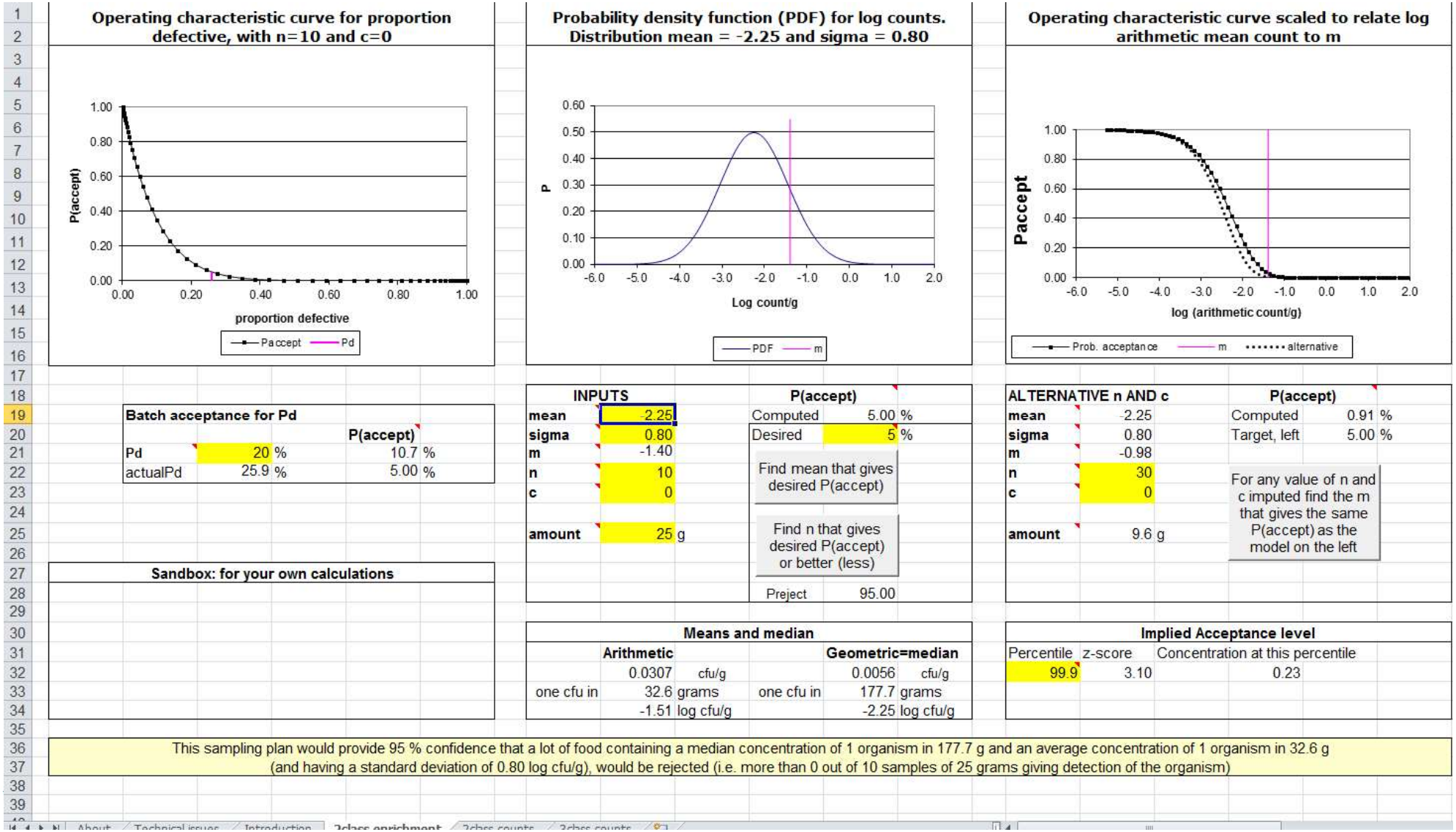
*Alternative approaches to the risk management of *Listeria monocytogenes* in low risk foods. Farber et al. Food Control 2021

http://www.icmsf.org



Three statistical phenomena are relevant:

1. the actual spatial distribution of microorganism in the food batch
2. the statistical process of taking a sample unit and it being defective $P_{defective}$
3. the acceptance of the plan based on n sample units, of which c are accepted to be positive and $P_{defective}$

For example

1. organism lognormally distributed in product
2. taking one sample is a Poisson process: $P_{defective}$ is a Poisson-lognormal distribution of contaminant in the sample unit
3. P_{accept} of a plan based on $P_{defective}$, n sample units, and c is a binomial process

P_{accept} is then a Binomial(Poisson(LogNormal)) distribution !

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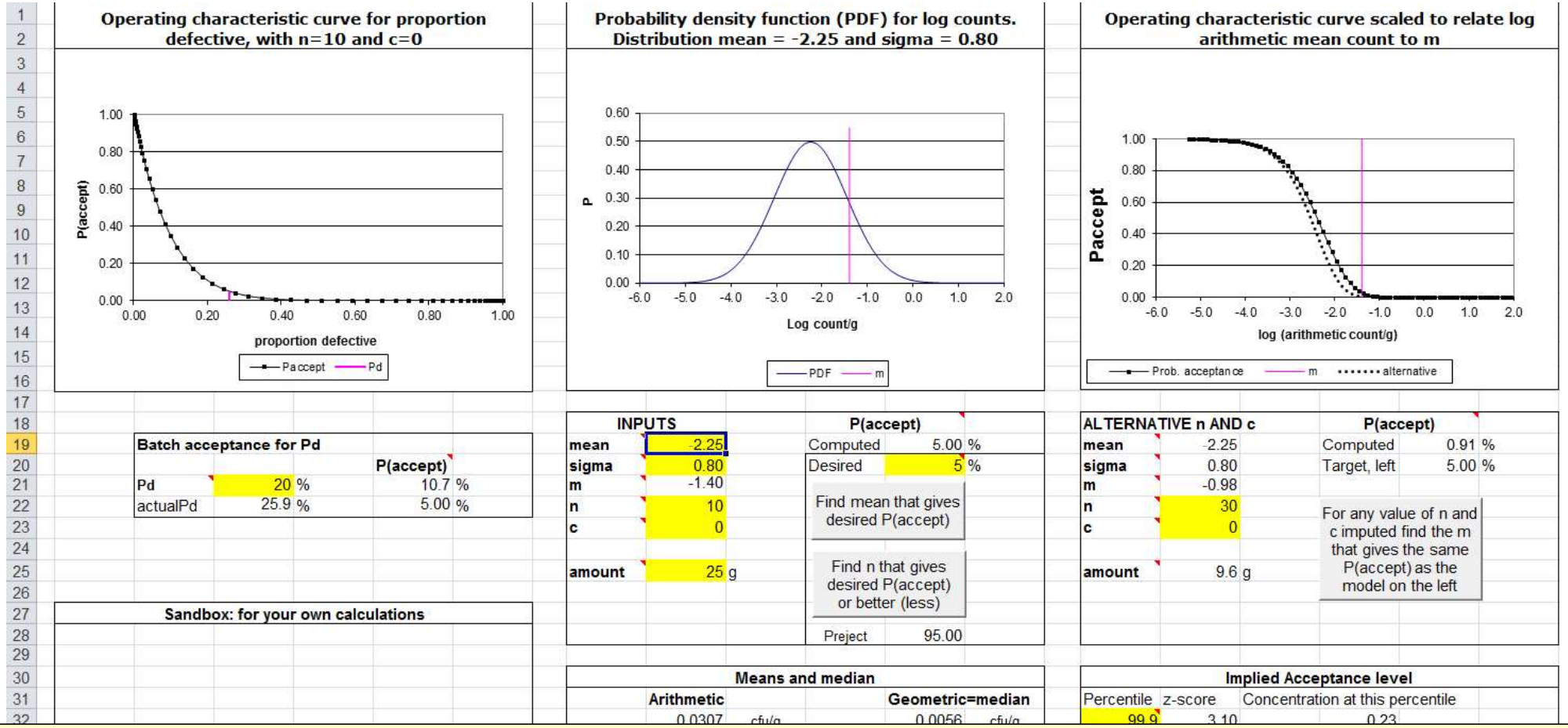
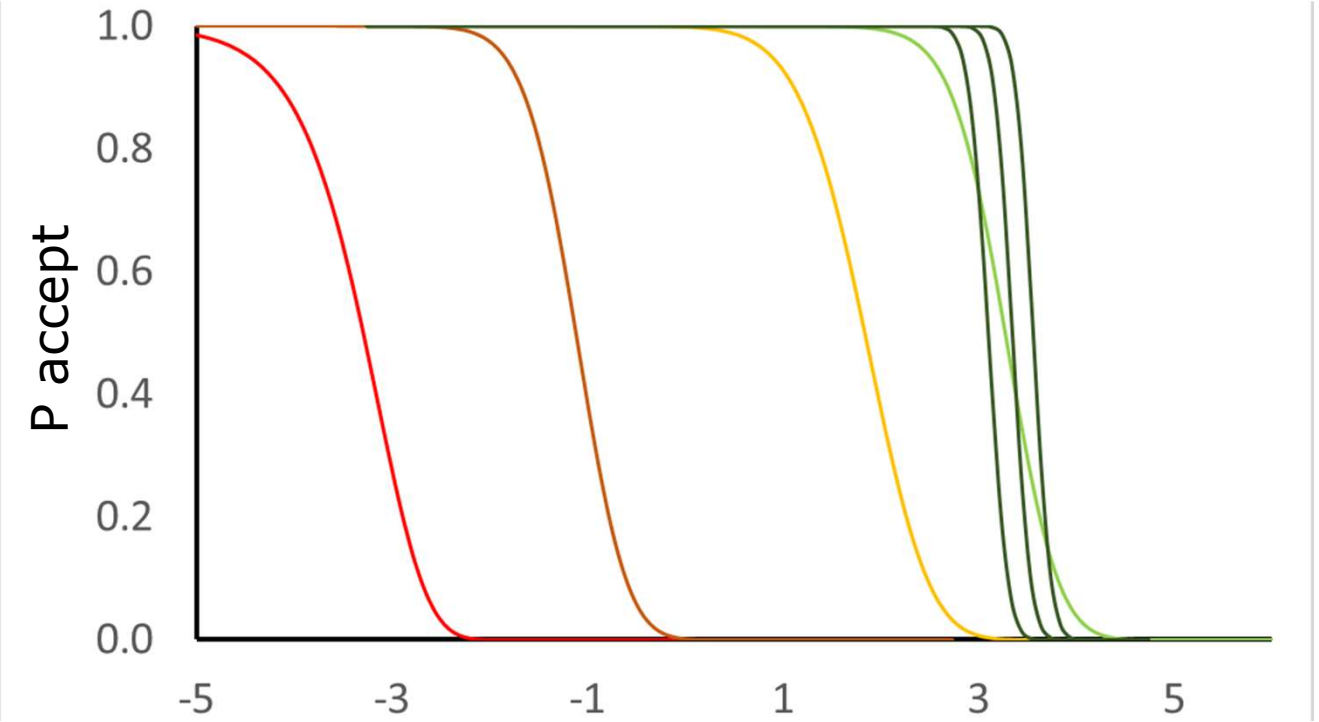
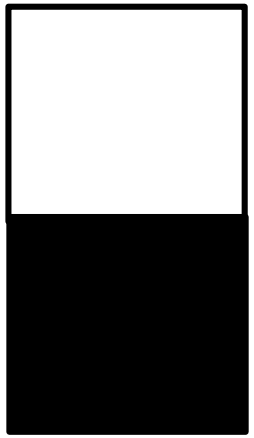


This sampling plan would provide 95 % confidence that a lot of food containing a median concentration of 1 organism in 177.7 g and an average concentration of 1 organism in 32.6 g (and having a standard deviation of 0.80 log cfu/g), would be rejected (i.e. more than 0 out of 10 samples of 25 g giving detection of the organism)

Performance (concentration detected with 95% P)





					cfu/g
Salmonella	*n*=60	*c*=0	0/25g		0.0027
Enterobacteriaceae	*n*=10	*c*=2	0/10g		0.34
Listeria	*n*=5	*c*=0	*m*=100 cfu/g		434
Campylobacter	*n*=50	*c*=20	*m*=1000 cfu/g		6155
Mesophiles	*n*=5	*c*=2	*m*=500 cfu/g	*M*=5000 cfu/g	8952

If life would be easy: what sampling plan to use

- Safety / Hygiene / Spoilage ?
- Pathogen or indicator ?
- qualitative/quantitative ?
- 2-class/3-class ?

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It depends ……

If life would be easy: what sampling plan to use

- Safety / Hygiene / Spoilage
- Pathogen or indicator: both (safety and hygiene)

- qualitative: for very infective organisms
- quantitative: only higher levels result in disease
- 3-class: if certain prevalence or levels are acceptable

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Conclusions

- Many different sampling plans exist
- Sampling can have different objectives
- Safety / Hygiene / Spoilage
- Focus at different places (ingredients, environment, end product)
- Sampling is no control
- Information for producers / governments
- Different types (2/3-class; qual/quant)
- Combination especially within a FSM systems gives confidence

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