

Food Sampling Plans and Environmental Sampling

PubH 7213

Applications of Microbiology to Food Systems Monitoring

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What is Sampling?

“A procedure used to draw inferences about a lot (population) from results obtained from a sample”

“To collect a representative sample to obtain information on its microbiological status”
(ICMSF, 2002)

Lot and Sample

- Lot:
A quantity of food or food units produced and handled under uniform conditions
- Sample:
A number of food units that resembles the microbiological characteristics of the lot

Why do we sample?

Sampling Plan

The particular choice of sampling procedure and the decision criteria used to accept/reject food lots

Objective: determine the minimum number of food units that will provide a high degree of certainty about the microbiological quality of a food lot

Sampling Plans

Critical factors (“the where, how, when, who and how many”):

1. Sampling point
2. Sampling procedure
3. Sampling frequency
4. Sampling personnel
5. Sample size

Sampling Steps

1. Sample collection
 - Containers
 - Sampling utensils and devices
 - Sampling procedures: aseptic technique
 - Sample labeling
2. Sample handling
 - Transportation
 - Reception
3. Sample analysis
 - Withdrawing analytical units
 - Homogenization of analytical units

Sample units (n)

■ Requirements:

1. Large enough to represent the population
2. Small enough to be economically feasible

Sample Units: Used Criteria

1. Sample size of zero
2. 100% sampling
3. Spot checking
4. Constant percentage, square root
5. Statistical samples

Sample Units: Criteria

Statistical samples

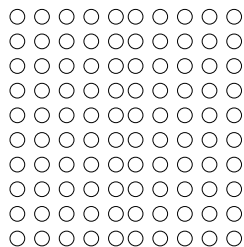
- Based on statistical schedules
- Sample has to be random
- Sample has to be representative
- Determine the sample size that will resemble the population's quality

Types of Random Samples

1. Simple

$N = 100$

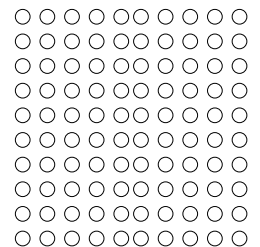
$n = 10$



Types of Random Samples

2. Systematic

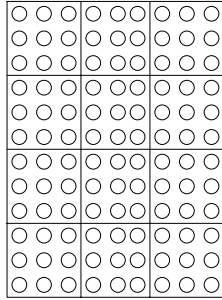
- After random selection of the k item per group, selects every kth. unit of the population



Types of Random Samples

3. Stratified

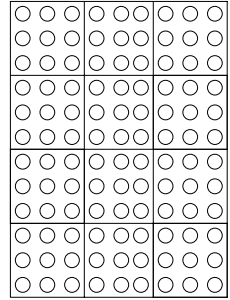
- Based on physical separation, the population can be divided into sub-sets (strata)
- Each stratum is randomly sampled to detect differences among the strata



Types of Random Samples

4. Cluster

- If the population is naturally divided in clusters, randomly selects clusters from which the population sample is taken



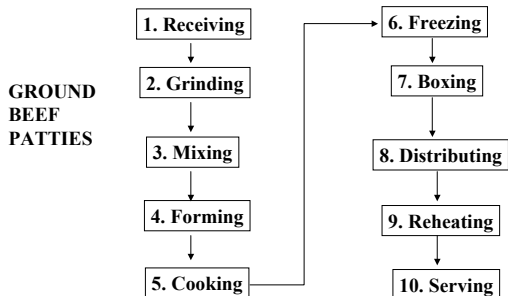
Examples of Lots

- Truckload
- 100-bag (or other number)
- Pallet-load lot
- Carcass number per shift

Sampling Frequency and Location

- Frequency:
 - Determined by the time that a variable or attribute remains within limits
- Location:
 - Critical control points after a kill step

Sampling Plan: Points of Collection



Sampling Plan Terms

- n – number of sample units
- c – maximum allowable number of samples exceeding a microbiological criteria
- Example:
 - 10 pork carcasses = n
 - Accept if 2 or less exceed 10 cfu/g *E. coli*, then, c=2

Sampling Plan Design

How do we know that an $n = 10$ and a $c = 2$ will ensure that we are accepting good lots and rejecting defective ones?

- We will never have a 100% assurance

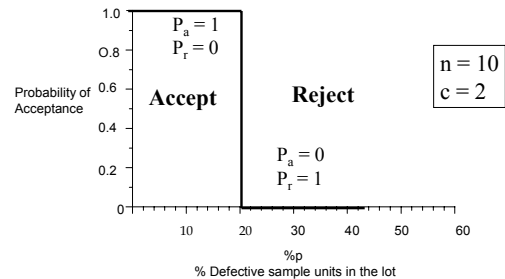
Sampling Plan Risks

- Producer risk (α): probability of rejection of acceptable lots
 - Maximum = 5%
- Consumer risk (β): probability of acceptance of defective lots
 - Maximum = 10%

Sampling Plan: Operating Characteristic Curves

- Relationship between the proportion of defective sample units in the lot (p) and the probability of accepting such lot (P_a)
- Determines α and β risks
- Constructed using binomial distribution

Operating Characteristic Curves: Ideal Case



Operating Characteristic Curves: Binomial Distribution

- Based on the presence (p) or absence ($q=1-p$) of a characteristic
- In quality, p is the probability of obtaining a defective number of item (c) and q the probability of obtaining non-defective articles, of a sample size n , such that:

$$P(c) = \binom{n}{c} q^{n-c} p^c$$

where

$$\binom{n}{c} = \frac{n!}{(n-c)!c!}$$

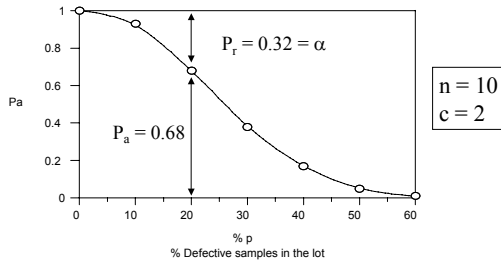
Operating Characteristic Curves: Calculation Example

- If $n = 10$ and $c = 2$ then

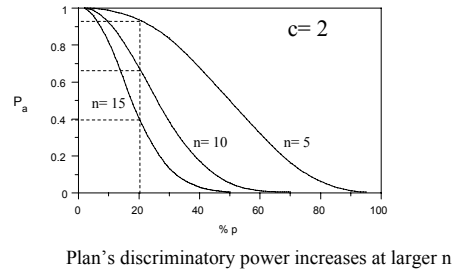
Assigning different proportion of defectives (p) P_a is calculated, tabulated and graphed:

% p	0	10	20	30	40	50	60
P_a	1.00	0.93	0.68	0.38	0.17	0.05	0.01

Operating Characteristic Curves: Calculation Example

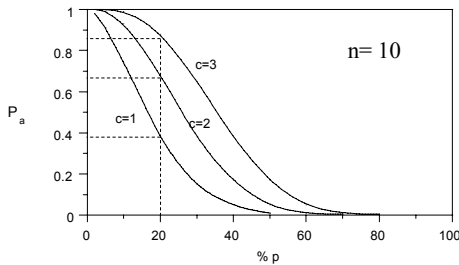


Operating Characteristic Curves: Effect of n



Plan's discriminatory power increases at larger n

Operating Characteristic Curves: Effect of c



Plan's discriminatory power increases at smaller c

Attributes Sampling Plans

1. Two-class

- Use only one microbiological criteria (m) to decide if a sample unit is acceptable or not
- m = lower limit

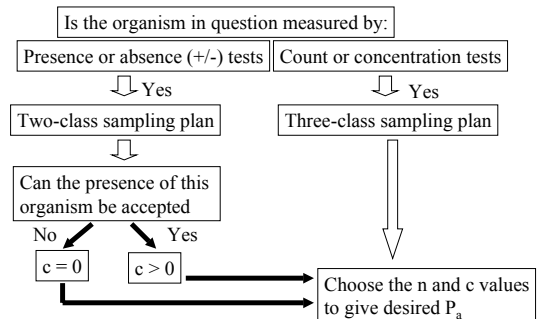
2. Three-class

- Use two criteria (m and M) to differentiate between acceptable, marginally acceptable and non-acceptable units
- M = marginal limit

Types of Microbiological Values for m and M

- Microbial counts – cfu/g, gu/g, cells/g
- Positive or negative

Attributes Sampling Plans: Decision Tree



Sampling Plan Stringency in Relation to Degree of Risk and Conditions of Use (ICMSF)

Hazard Type	Typical conditions of handling after sampling		
	Reduce risk	No change	Increase risk
No direct health hazard	Case 1	Case 2	Case 3
Low hazard, indicator	Case 4	Case 5	Case 6
Moderate hazard, not life threatening	Case 7	Case 8	Case 9
Serious hazard, not usually life-threatening but incapacitating	Case 10	Case 11	Case 12
Severe hazard, life-threatening, long illness or sequelae	Case 13	Case 14	Case 15

Recommended Sampling Plans for Each Case

Cases	n	c	Type
1, 4	5	3	Three-class
2, 5, 7	5	2	Three-class
3, 6, 8	5	1	Three-class
9	10	1	Three-class
10	5	0	Two-class
11	10	0	Two-class
12	20	0	Two-class
13	15	0	Two-class
14	30	0	Two-class
15	60	0	Two-class

Current Sampling Plans:
Pork Slaughtering Plants

■ *Escherichia coli*

- Mandatory and conducted by the plant
- Frequency
 - » Large plants: 1 carcass per 1000 heads
 - » Small plants (<6,000 per year) 1 sample/week for 13 weeks during June-August
- n = 13, c = 3
- m < 10 cfu/cm², M < 10,000 cfu/cm²

Current Sampling Plans:
Pork Slaughtering Plants

■ *Salmonella*

- Part of the Salmonella Performance Standards program and conducted by government inspectors
- For HACCP plan assessment
- Frequency 1 sample unit/week
- n = 55, c = 6
- If c > 6, the plant has to re-assess its HACCP plan
- If the plant fails 3 times, it may be closed (Remember Supreme Beef lawsuit)

Current Sampling Plans:
Ready-to-eat Meats

■ *Listeria monocytogenes*

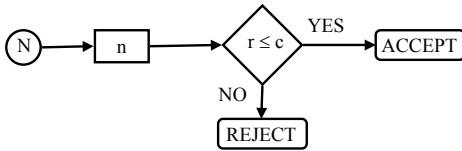
- Option 1: the government inspector obtains 1 sample/month for products covered under each HACCP plan
- Option 2: the government inspector collects 1 sample/ 3 months if:
 - » The plant has a monitoring program in place for *Listeria spp.* and tests for *L. monocytogenes* when positive *Listeria* indicator samples

Current Sampling Plans:
Pasteurized Dairy Products

- According to the PMO, milk and milk products should be sampled a minimum of 4 times in 6 months for bacteriological quality and standards compliance
- State inspectors collect 1 sample/ 6 months
- Routine analyses: APC, coliforms
- Other random analyses: *Salmonella*, *Listeria*, *Campylobacter*, *Staphylococcus*, yeasts and molds

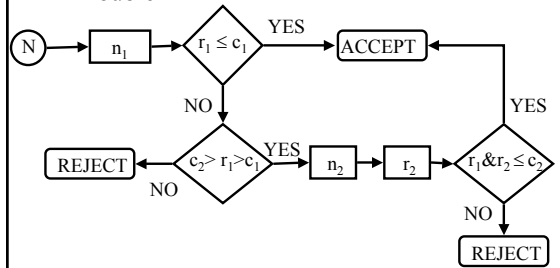
Sampling Plans

■ Simple



Sampling Plans

■ Double



Attribute Sampling Plan Development

- Use of MIL STD 105E
- Steps to formulate a sampling plan
 1. Decide on lot size, confidence level (General inspection), and select code letter from Table A-9
 2. Find this letter in Table A-10 and the corresponding sample size
 3. Decide on the acceptable quality level and find the accept/reject level

Sampling Acceptance Terms

- Acceptance Quality Level (AQL)
 - Proportion of defectives that we would be willing to tolerate in the lot

Attribute Sampling Plan Development

- MIL STD 105E
- <ftp://www.variation.com/pub/milstd105e.pdf>

CFR on sampling

- http://www.access.gpo.gov/nara/cfr/waisidx_00/7cfr43_00.html

Attribute Sampling Plan Development

- Example 1:
 - Lot size = 2000, AQL = 2.5%
 - Determine n and c at 95 and 99% confidence
- Example 2:
 - Lot size = 50, AQL = 1%
 - Determine n and c at 90 and 95% confidence

Environmental Sampling

- Why are we concerned with microorganisms in the environment?
- Examples of outbreaks involving environmental contaminants?

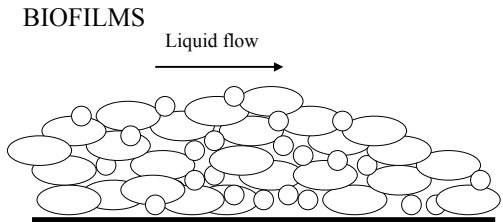
Environmental Sampling

- Post-process contamination
 - Contaminated ingredients
 - Environmental contaminant

Microbial Ecology of the Food Processing Environment

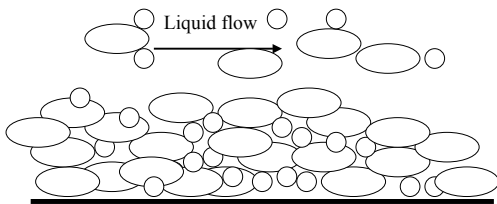
- Types of microorganisms:
 1. Transient
 2. Resident
 - Most persistent: *L. monocytogenes*, *Salmonella*
 - Somewhat persistent: *S. aureus*, *E. coli* O157:H7, *Y. enterocolitica*, *B. cereus*, *C. botulinum*, *C. perfringens*
 - Not persistent: *S. typhi*, *Shigella*, *C. jejuni*, viruses, parasites

Environmental Sampling



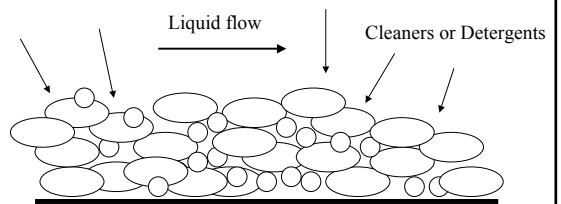
Environmental Sampling

Biofilm break-down



Environmental Sampling

Biofilm break-down



Environmental Sampling

Purposes:

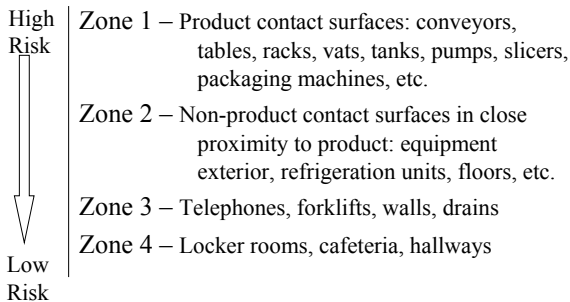
- Assess the risk of product contamination
- Determine if the environment is under control
- Investigate the source of contamination to implement corrective actions

Environmental Sampling

Where to sample????

Criteria based on level of risk

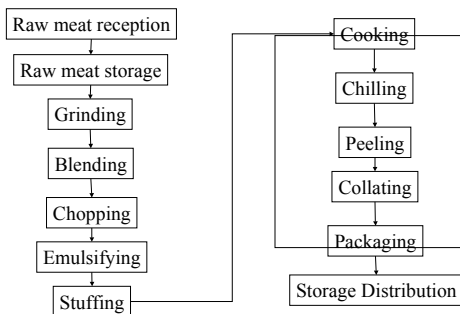
Environmental Sampling: Location



Environmental Sampling: Location Example

In a Frankfurter sausages operation what places would you sample?

Environmental Sampling: Location Example



Environmental Sampling Plans

- Based on experience and knowledge related to GMP's
- Plans should include:
 - Location
 - Number
 - Frequency
 - Time of sampling

Environmental Sampling

Types of samples:

- Swabs of surfaces
- Solid residues on surfaces, holes, crevices
- Dust
- Liquid residues

Environmental Sampling

Sampling tools:

- Sponges, cotton pads, utensils, cups, bags
- Spatulas, scrapers, brushes
- Pipettes

Environmental Sampling Plan Example

Location	Frequency	
	Normal	Increased
Equipment sponge samples		
Brine chill solution	1 x week	1-3 x day
Peeling table	1 x week	1-3 x day
Hopper/incline conveyor after peeler	1 x week	1-3 x day
Collator	1 x week	1-3 x day
Conveyor before packaging	1 x week	1-3 x day
Packaging machine	1 x week	1-3 x day

Environmental Sampling Plan Example (cont'd)

Location	Frequency	
	Normal	Increased
Finished Product		
Finished product	1 x biweekly	1-3 x day
Environmental sponge samples		
Floor in peeler area	1 x week	1-3 x day
Floor in vicinity of collating and packaging line	1 x week	1-3 x day

Food Sampling Plans and Environmental Sampling Summary

References

- ICMSF 2002. Microorganisms in Foods 7. Microbiological Testing in Food Safety Management. Kluwer Academic, New York
- Hubbard, M. R. 1996. Statistical Quality Control for the Food Industry. 2nd Ed. Chapman and Hall, New York