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Effective sampling strategy to detect food and feed contamination: Herbs and spices case

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A B S T R A C T

Sampling plans for food safety hazards are aimed to be used to determine whether a lot of food is contaminated (with microbiological or chemical hazards) or not. One of the components of sampling plans is the sampling strategy. The aim of this study was to compare the performance of three different sampling strategies, being simple random sampling (SRS), stratified random sampling (STRS), and systematic sampling (SS), with each other for their probability of detecting a heterogeneously distributed contamination in a lot of herbs or spices (i.e., a dry food product). To this end, a simulation model was developed, and applied to different scenarios for contamination level and numbers of samples collected. In addition, as a case study, the sampling plan of a company processing herbs and spices was evaluated using the simulation model. Results showed that the effectiveness of the sampling plan is influenced by the sampling strategy. With expected low contamination levels the SS strategy performs better than the two other strategies. At higher expected contaminated levels, the STRS strategy is preferred.

1. Introduction

A test procedure for a potential (microbiological or chemical) contamination in a feed or food product generally consists of the following three steps: (i) sampling, (ii) sample preparation, and (iii) analyses. The sampling step consists of selecting a subset of samples from one lot to estimate pre-defined characteristics of the whole lot (Christakos, 1992; Wang, Stein, Gao, & Ge, 2012). The sample preparation step includes, for example, grinding the sample in a mill to reduce its particle size, and taking a subsample of ground homogenised material from the sample. The analytical step consists of several steps in which the contaminant is extracted from the subsample and is quantified using analytical techniques (Whitaker, 2003). For economic reasons, often, a very small quantity of the lot is finally used for quantification of the contamination, and the weight and the number of samples of the product used at each step of the procedure is continually reduced to smaller amounts (EC, 2006).

Previous studies have looked at the design of sampling plans for different products and contamination levels. For instance, Coker et al. (1995) reviewed the complexity related to the design of sampling plans for mycotoxins in food and feed. In their study, they included different commodity types, sample composition, sample preparation, and analytical steps. They showed that in commodities composed of large particles (e.g., corn and oilseed kernels) at least one hundred incremental samples are required to obtain a 10 kg representative aggregate sample.

The choice of the sampling strategy is very important in the design of a sampling plan (Battilani, Barbano, Rossi, Bertuzzi, & Pietri, 2006; Rivas Casado, Parsons, Weightman, Magan, & Origgi, 2009), especially, when the contamination is heterogeneously distributed in a lot, such as with mycotoxins (Johansson, Whitaker, Giesbrecht, Hagler, & Young, 2000; Schatzki, 1995). Many choices can be made for the method of selecting the sample, the sample size and the number of samples to be taken (Whitaker, 2003).

In literature, several sampling strategies have been proposed to design sampling plans that include non-probability (Baker et al., 2013) and probability sampling strategies (Wang, Haining, & Cao, 2010). The non-probability category includes: accidental sampling, quota sampling, and purposive sampling also called judgment sampling. In these approaches the selection of elements is based on assumptions regarding the population of interest, which forms the criteria for selection (e.g. stopping the first hundred). However, the probability sampling strategies are based on probabilities and statistics. This category contains: simple random

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sampling, stratified random sampling, systematic sampling, cluster sampling, multistage sampling. More details on these techniques can be found in Appendix (see Table A.1) and (Christakos, 1992; Haining, 2015; Thompson, 2012; Wang et al., 2012).

The main probability sampling approaches used in literature in food safety to detect chemical and microbial contamination in a batch of food or feed are: simple random sampling (SRS) stratified random sampling (STRS) and systematic sampling (SS). Generally, these strategies can be implemented easily and have a good precision (see Table A.1). For instance, the SRS strategy is used in EU regulation in sampling of carcasses of cattle, pigs, sheep, poultry, goats and horses for the *Salmonella* analyses (EC, 2007). Jongenburger and colleagues (Jongenburger, Reij, Boer, Gorris, & Zwietering, 2011) compared these three strategies in the detection of a localised contaminated batch of food. Also, Casado and colleagues (Rivas Casado et al., 2009) assessed the use of SS and SRS strategies in detecting mycotoxins in bulk commodities.

The aim of this study was to evaluate three different sampling strategies, being SRS, STRS, and SS, for their ability to detect a contamination that is heterogeneously distributed in a lot of herbs and spices. As a case study, the sampling strategy of a company producing herbs and spices was evaluated using the developed model.

2. Material and methods

2.1. Sampling strategies

Three different sampling strategies were compared for their performance, i.e. their ability to detect a contamination that is heterogeneously distributed in the lot. The sampling strategies included are: SRS, STRS and SS. These strategies are illustrated in Fig. 1, an example of sampling 20 batches from a lot of 100 batches.

2.1.1. Simple random sampling

SRS is the strategy of selecting n batches randomly out of the total batches N such that every one of the possible distinct samples has an equal chance of being drawn. The batches in the population are numbered from 1 to N. A series of random n numbers between 1 to N are then drawn by means of a computer program (Cochran, 1977). With SRS, the probability that the i^{th} unit of the population is included in the sample is $P_i = \frac{n}{N}$, so that the inclusion probability is the same for each unit.

In case of a lot with a homogenous distributed contamination, the probability to detect the contamination is the same for each sample. In this case, the strategy in which the samples are drawn from the lot does not influence the sampling plan (Jongenburger et al., 2011). More details can be found in Appendix (see Table A.1 and Table A.2)

2.1.2. Stratified random sampling

In the STRS strategy, the population of N batches is first divided into L subpopulations of $N_1, N_2, \ldots, N_L$ batches, respectively. The subpopulations are called strata. When the strata have been determined, a sample is drawn from each stratum, the drawings being made independently in different strata (Cochran, 1977; Jongenburger et al., 2011). These subpopulations are not overlapping, and together they comprise the whole of the population, so that $N_1 + N_2 + \ldots + N_L = N$.

Using STRS strategy, the heterogeneity in each stratum is reduced and it is easier to collect representative samples (Wang et al., 2010). More details about the STRS strategy can be found in Appendix (see Tables A.1 and A.2)

2.1.3. Systematic sampling

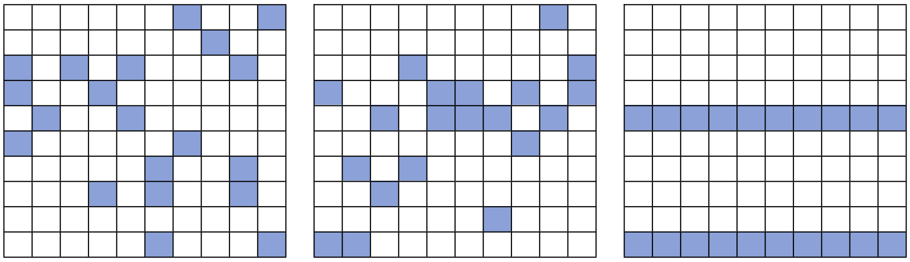
The SS strategy stratifies the population into L strata, which consist of the first k batches, the second k batches, and so on. The population of N batches are numbered 1 to N in some order. To select a sample of n batches, a unit is taken at random from the first k batches and every k^{th} unit thereafter. For example if k is 15 and if the first unit drawn is number 13, the subsequent batches are numbers 28, 43, 58, and so on. The selection of the first unit (In this case generated randomly) determines the location of each sample. This strategy is also called an every k^{th} systematic sample (Cochran, 1977; Jongenburger et al., 2011).

The SS strategy has several advantages comparing to the SRS strategy: i) With SS, it is easier to draw a sample and often easier to execute without mistakes, ii) SS seems to be more precise than SRS (Thompson, 2012; Wang et al., 2010; Wang et al., 2012). If the contamination is heterogeneously distributed in a lot, the SS was reported to be more effective to detect a the contamination (Habraken, Mossel, & Reek, 1986). For more details (see Table A.1 and Table A.2).

2.2. Simulation model

A simulation model was developed to compare three sampling strategies (SRS, STRS, and SS) for their effectiveness in detecting an heterogeneous contamination in a lot of food. The effectiveness of these sampling strategies depends mainly on two factors which are the contamination level and a number of samples collected. The contamination level is defined as the percentage of batches, from the entire lot, that were contaminated.

In this simulation model, we assumed that:



a) SRS b) STRS c) SS

Fig. 1. Example of sampling 20 batches from a lot of 100 batches: simple random sampling (SRS) (a), stratified random sampling (STRS) (b), and systematic sampling (SS) (c).

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