Optimization Algorithms vs. random sampling of entry sources for a deliberate food contamination

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Abstract: We focus on a deliberate scenario, where milk producers are used as entry sources for a contamination and where milk consumers are the target of the attack. The aim of this study is to demonstrate how the size of damage differs dependent on the use of an optimization algorithm or a random selection of entry sources. The results indicate that with a random selection of entry sources the same results can be provided with respect to the number of consumers reached, as with the application of the greedy algorithm. However, it should be also noted that with random selection of entry sources there is also a possibility of selecting milk producers, which would not reach any consumer with the hypothetical contaminated milk. The résumé is that by using the greedy algorithm always the "best" suited milk producers will be selected for a maximum spread of contaminated milk in our model. Risk managers can use these results in order to select the sources of entry in a time- and resource efficient manner.

1 Introduction

Risk managers are often confronted with the difficulty of assessing the potential consequences of a foodborne outbreak [Du09]. Modeling can be useful to assess the possible consequences of an outbreak [Ga07]. Authors of several research studies in the agriculture and food science focused on the exploration of a spotty introduction of a pathogen in a food supply chain [WL05]. This study deals with a somehow related approach from a different perspective: How much entry sources are required to achieve a maximum damage situation (worst-case situation, where all consumers are supplied with contaminated milk)? We focus on a deliberate scenario, where milk producers are used as entry sources for a contamination and where milk consumers are the target of the attack. The aim of this study is to demonstrate how the size of damage (quantificated by the number of consumers reached, caused by infected milk producers) differs when an optimization algorithm or a random selection of entry sources is used in a deliberate contamination, respectively.

2 Material and Methods

The milk trade model[1] consists of 294 milk producers, 80 dairies, 12,223 consumers [Pi12] and contains 73,338 trade connections between these actors. In the study by [PCPS13] the 294 milk producers were hypothetically infected in the computer simulations (50 iterations) and were sorted according to their damage situation (in terms of the number of contaminated consumers reached) by the application of the greedy algorithm [PCPS13]. The greedy algorithm searches for the "best" milk producer (P) according to the number of reached consumers (C) and then follows the next "best" milk producer, which causes a maximal increase of further contaminated consumers, which were not reached by the first milk producer [PCPS13]. In this context, the condition was that the number of milk producers, who are involved in the spread, should be minimal (min{p:p ∈ P}) and all consumers (maximal damage size: max{c:c ∈ C}) should be supplied with the contaminated milk [Pi13; PCPS13], whereby the conditions must be fulfilled that a trade link between producer and dairy (p ∈ D) as well as between dairy and consumer (c ∈ D) exists (equation 1).

$$\max \left|\{c\colon c \in C; \min|\{p\colon p \in P\}|, p \in D, c \in D\}\right| \quad (1)$$

In this work milk producers were selected randomly as entry sources. In the first step, a random selection of one milk producer as entry source was conducted 200 times and the according damage size was calculated. In the second step, 200 random selections of two milk producers as entry sources were conducted and the cumulative damage sizes were computed. This procedure was continued up to 200 random selections of 20 milk producers as entry sources (Figure 1). This damage situation caused by random selection of entry sources was compared with the selection of entry sources from the greedy algorithm.

3 Results

[PCPS13] shows that the number of milk producer as entry sources in order to reach all consumers (100%) with contaminated milk was minimum 15 and maximum 20 (during 50 iterations performed). One milk producer (represents the best or first milk producer as entry source) is able to infect more than 68% of all consumers. The milk producers as second entry sources led to a further maximum increase of reached consumers of 12,2%,

[1] The underlying milk trade model is described in detail by [Pi12] and [Pi13]

which means that the first and second milk producer can reach about 80% of the consumers.

In the first step of the random selection, 200 random selections of one milk producer as entry source were made. The percentage of reached consumers in this selection is between 0% and 68% (Figure 1).

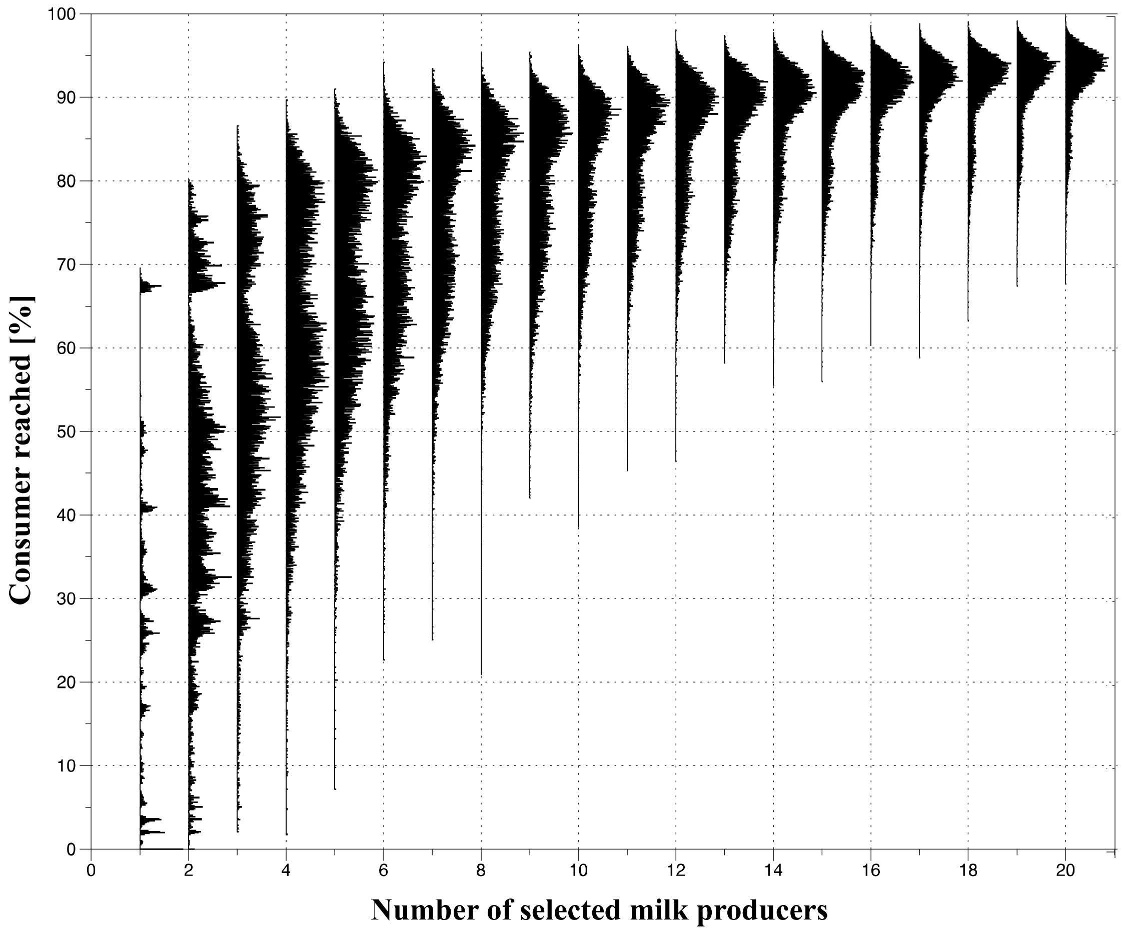

Figure 1: Hypothetically infected consumers by selection of random milk producers: At the point, where two milk producers are selected, the cumulative number of consumers reached is presented by the two milk producers for the 200 random selections. For each number of randomly selected milk producer the selection was conducted 200 times. The width of the bars (per number of selected milk producers), illustrates how often the milk producers from the 200 times random selections caused the same size of damage (frequency distribution).

If two milk producers are selected 200 times randomly, they can reach together 0% to 80% of the consumers. If the number of selected milk producers increases (e.g. three milk producer are selected 200 times), the cumulative damage amounts to more than 0% consumers reached (Figure 1). With 20 milk producers as entry sources of contamination all consumers can be reached.

4 Conclusion

The conclusion is that with the application of the greedy algorithm always the “best” suited milk producers will be selected for a maximum spread of contaminated milk in our model. In a random selection of entry sources there is also a possibility of selecting milk producers, which would not reach any consumer with the hypothetically contaminated milk.

Risk managers can use these results in order to select the sources of entry in a time- and resource efficient manner. Furthermore it should be noted that a responsible use of data on supply structures is necessary in order to reduce the potential attack targets in the agri-food sector to a minimum.

References

[Du09] Dubè, C.; Ribble, C.; Kelton, D.; McNab, B. (2009): A Review of Network Analysis Terminology and its Application to Foot-and-Mouth Disease Modelling and Policy Development. Transbound. Emerg. Dis., 56, pp. 73-85.

[Ga07] Garner, M. G., Dubé, C., Stevenson, A. M., Sanson, R. L., Estrada, C., Griffin J. (2007): Evaluating alternative approaches to managing animal diseases outbreaks-the role of modelling in policy formulation. Vet. Ital., 43, pp. 285-298.

[Pi12] Pinior, B.; Konschake, M.; Platz, U.; Thiele, H.; Petersen, B.; Conraths, F.C.; Selhorst, T (2012): The Trade network in the dairy industry and its implication for the spread of a contagion. Journal of Dairy Science, Vol. 95 (11), pp. 6351-6361.

[PCPS13]Pinior, B.; Conraths, F.C.; Petersen, B.; Selhorst T. (2013): Decision support for risks managers in the case of deliberate food contamination: The Milk Supply Chain as an example (under review).

[Pi13] Pinior, B.: Application of models for safeguarding the milk supply chain. PhD-Thesis, University of Bonn, 2013; 122 p.

[WL05] Wein, M. L.; Liu, Y. (2005): Analyzing a bioterror attack on the food supply: The case of botulinum toxin in milk. PNAS, 102(28), pp. 9984-9989.