Food Control xxx (2017) 1–6

Contents lists available at ScienceDirect

Food Control

journal homepage: www.elsevier.com/locate/foodcont

Network and vulnerability analysis of international spice trade

Zoltán Lakner [a,*], Erzsébet Szabó [b], Viktória Szűcs [b,c], András Székács [d]

[a] Faculty of Food Science, Szent István University, Villányi u. 29-43, H-1118, Budapest, Hungary
[b] Food Science Research Institute, National Agricultural Research and Innovation Centre, Herman Ottó u. 15, H-1022, Budapest, Hungary
[c] Directorate of Food Industry, Hungarian Chamber of Agriculture, Fehérvári u. 89-95, H-1119, Budapest, Hungary
[d] Agro-Environmental Research Institute, National Agricultural Research and Innovation Centre, Herman u. 15, H-1022, Budapest, Hungary

ARTICLE INFO

Article history:
Received 12 October 2016
Accepted 26 May 2017
Available online xxx

Keywords:
Chilli
Dyadic analysis
Red pepper
Stochastic simulation

ABSTRACT

The spice trade network is one of the oldest and substantially vulnerable systems of the agri-food supply chains. Based on statistical analysis of spice paprika (chilli red pepper) and black pepper trade flows within the EU member states, stochastic simulation models have been developed for prognosis of the proliferation of contaminated products between the member states as a function of the source-state of the contaminated products. Results highlight the rapidity of proliferation, and offer a simple, but robust tool for prediction of contamination patterns among states, serving the formation of a targeted defence strategy and policy Traditional geostatistical methods (e.g. Morens' *I* of spatial autocorrelation) in most cases are not suitable to predict the geographic distribution of contaminated products among countries, due to complexity and inter-connectedness of the European spice network. The pattern of proliferation of contaminated products between member states was analysed using a dyadic network of relational data, applying additive and multiplicative effects model. Results of analysis prove the importance of long-distance, international trade in distribution of contaminated products.

1. Introduction

Long-distance trade of spices has formed one of the first global product trade networks (Gilboa & Namdar, 2015). The spice trade development originates through South Asia and Middle East from around 2000 BCE with cinnamon (Lee & Balick, 2005) and pepper (Parry, 1955). In the holy text of Judaeo-Christian culture, the Book of Genesis of the Old Testament, Joseph was sold into slavery by his brothers to spice merchants (Genesis, 37). In the middle ages, spice trading was a driver of international trade development (Loewe, 1971) and colonialization (Ashtor, 1980). Since the 1960s, the quantity of global spice trade has been increasing at an exponential rate (Fig. 1), the value of international spice trade (in nominal terms) increased 41-fold, showing a slightly higher rate, than that of the overall food trade increase (D'Odorico, Carr, Laio, Ridolfi, & Vandoni, 2016; FAOSTAT, 2016).

Agri-food product networks between countries form a complex, dynamic web of interactions (Petroczi, Nepusz, Taylor, & Naughton, 2011; D'Odorico et al., 2016), and the application of network analysis is a suitable method for studying it (De Benedictis, Nenci, Santoni, Tajoli, & Vicarelli, 2014; Nepusz, Petróczi, & Naughton, 2012). By definition (Börner, Sanyal, & Vespignani, 2007), network science concerns the study of different networks whether they are social, biological, technological or scholarly (Barabási and Albert, 1999; Albert, Jeong, & Barabási, 2000; Boccaletti, Latora, Moreno, Chavez, & Hwang, 2006; Karsai et al., 2011). The international trade in spices can also be considered as a network, where the nodes are the states, and the edges are trade flows between states.

Structural changes in the world spice market can be well traced from the example of red chilli peppers (hereinafter: chilli peppers). Fig. 2 depicts the network of the world chilli pepper trade in average to 1986–1991 and 2009–2013, applying the Fruchterman-Reingold algorithm. The size of nodes are approximately proportional with their weighted out-degree (a measurement of product flows out of this node (Menichetti, Dall'Asta, & Bianconi, 2014), the colour of nodes with their high level of centrality, which is a measurement of a central position of a node (in this case) within a network (Barthelemy, 2004). It is obvious, that the number of actors (states) and complexity of networks has considerably increased. The lighter colour of India, as a central actor in period 2009–2013 is an indicator of more decentralised characteristics of this network.

Spice trade has numerous specific aspects compared with trade

* Corresponding author.
E-mail address: lakner.zoltan@etk.szie.hu (Z. Lakner).

http://dx.doi.org/10.1016/j.foodcont.2017.05.042
0956-7135/

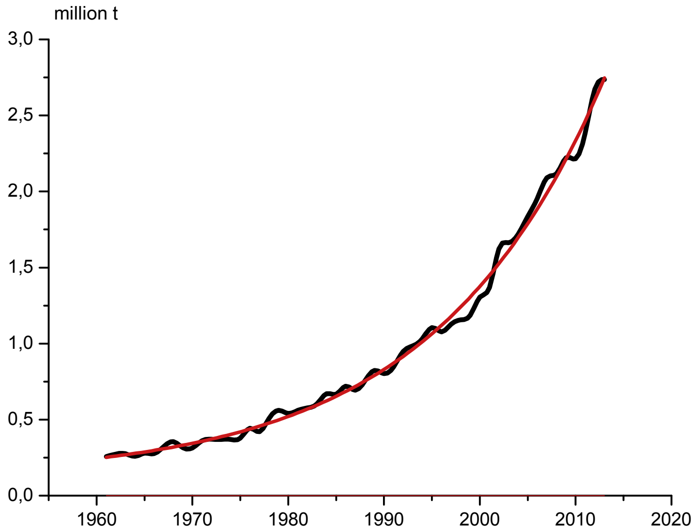

Fig. 1. Increase of the international spice trade between 1961 and 1013 and its approximation by exponential growth function $y = 112622 + 131155e^{(t-1959)/17.68}$ (where y: annual trade volume in million tonnes; x: year) ($r^2 = 0.995$) (Source: own calculations on the basis of FAOSTAT data at http://faostat.fao.org).

of the majority of agri-food products, because: (1) there is a considerable geographic distance between the most important suppliers and buyers, which is why the international spice trade requires a considerable, long-distance transport and difficult logistical system (Henson & Loader, 2001); (2) the most important spice producing countries are relatively lesser developed ones, India, Bangladesh, Pakistan, Iran, Nepal, Colombia, Ethiopia and Sri Lanka being among the top ten most important exporters. Increasing political instability in a number of important Middle and Central Asian countries has further increased the unpredictability of some key actors (nodes) in the spice chain; (3) mixing of products from different geographical places of origin is a widely used practice among spice producers; (4) spices are widely used in a range of food products (e.g. in meat, poultry processing and canning industry) (Zhang, Gu, & Lu, 2009) as well as in gastronomy (Sherman & Billing, 1999). Under these conditions an eventual food safety problem with spices (Henson & Loader, 2001) can cause considerable economic and long-ranging moral losses.

While the importance of spice trade is widely acknowledged, the structure and conduct in terms of geographical distribution of contaminated products is hardly known. The aim of this study has been to analyse and model the international spice trade network, based on long-range data. Novelties of the current research approach are: (1) application of network science concept and methodology in the analysis of international spice flows; (2) presentation of a detailed model for vulnerability analysis of the spice trade network by agent-based simulations; (3) application of a dyadic analysis on determination of patterns of contaminated products; (4) investigation on applicability of geostatistical methods for forecasting of the international proliferation of contaminated products.

Based on analysis of the scientific literature and interviews with authorities of international spice trade, we formulated three research hypotheses:

H_1: as a consequence of tight economic relations between EU member states there is a rapid proliferation of contaminated products between the states;
H_2: the patterns of geographic distribution of contaminated products can be analysed by geospatial methods, and on this basis relatively well-separable clusters of regions with contaminated products can be identified;
H_3: distribution of contaminated products can be predicted on the basis of H_{3a}: the geographic proximity of countries and H_{3b}: on the basis of their level of economic development.

2. Methods

2.1. Stochastic simulation of trade flows

The stochastic simulation model was built in two phases: data were obtained and elucidated, with boundaries of the investigations determined in the first phase, and simulations carried out in the second phase. We localised our investigations to the European Union (EU28), because this economic entity can be considered as a relatively coherent network, having a food safety system easily distinguishable from its neighbours (Nepusz et al., 2012). Data for the investigation were obtained from the Eurostat system (EUROSTAT, 2016). For its comprehensiveness, this system is widely used for international trade analysis (de Frahan and Vancauteren, 2006). Based on Eurostat data, a database was constructed on the international trade flow of red pepper (HS Code: 09042090 - Crushed or ground fruits of genus Capsicum or pimenta; for simplicity, we neglected the pimenta trade, as it is

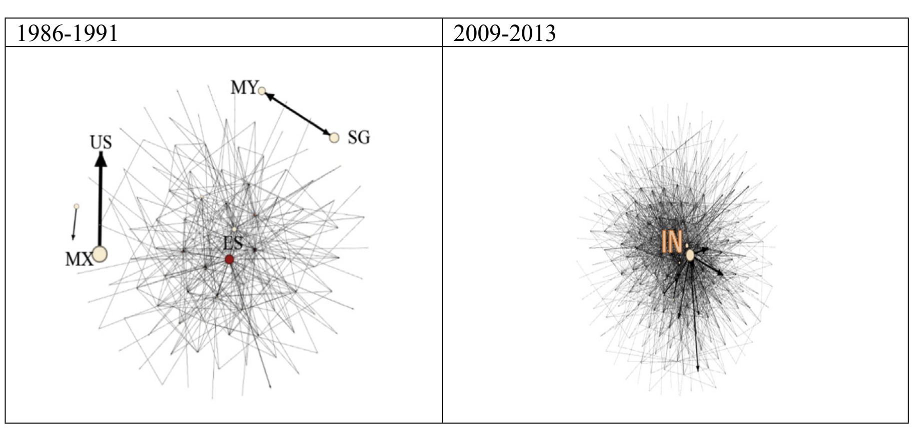

Fig. 2. The international chilli pepper trade network (Source: own calculations on the basis of FAOSTAT data at http://faostat.fao.org; for denomination of countries the official two- and three-letter ISO country codes, searchable at https://www.iso.org/obp/ui were applied.).