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European research and the Hungarian school of food irradiation

Zoltán Lakner [a,*], Sándor Soós [b], Zsófia Vida [b], Csilla Farkas [c]

[a] Dept. of Food Economics, Faculty of Food Science, Szent István University, Budapest, Hungary
[b] Dept. of Science Policy and Scientometrics, Hungarian Academy of Sciences, Budapest, Hungary
[c] Dept. of Microbiology and Biotechnology, Faculty of Food Science, Szent István University, Budapest, Hungary

HIGHLIGHTS

- Food irradiation had developed in cold war era in two systems in a parallel way.
- Scientometrics can reveal the central role of a person within network of scientist.
- Farkas had been able to exploit the window of opportunities to establish a school.
- Farkas has been an important hub of international research in food irradiation.

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ABSTRACT

In second half of the 20th century the research of application of irradiation to food preservation become a new and prospective field of food science and technology. This activity has been supported and developed in a parallel way in both halves of the that-time world, divided by the iron-curtain. Under these conditions, fulfilling a specific "bridge-role", some highly innovative scientists, first of all Professor József Farkas has been able to achieve considerable results in this new field of science. Based on citation analysis and science mapping it can be proven, that his path-breaking research has been exercise a fertilising effect on development of a wide range of fields of science, and considerably contributed to proliferation of this science and technology in numerous countries of the world.

1. Introduction

According to Diehl (2001) the development of food irradiation in the last century can be divided into three periods: the first half of the century there had been emerging pioneering studies on effects of ionising radiation to microorganisms and insects; between 1950 and 1970 the research had been focussing on application of irradiation in food preservation, insect disinfestation and sprout inhibition by optimization of technological parameters, in last decades of the century the research had been concentrating on problems in integration of food irradiation technology into the societies, analysing its nutritional, ethical, legal, and marketing aspect.

Early history of emergence of food irradiation, as well as the technology development in second phase are well documented (Josephson, 1983), but our level of knowledge on development of food irradiation technology is relatively low.

However, the application of irradiation of food has been relatively high in eastern states. This has been promoted by four factors: (1) Based on a wide range of specialised scientific research institutions, backed by such leadings scholars as Landau and Tamm (Фандо, 2014), the analysis of effects of irradiation of biological organisms has achieved considerable results in Soviet Union (Rogachev, 1966); (2) In opinion of Josephson (1996) "in each period of its history, the Soviet Union embraced large-scale technologies with an energy that belied its economic backwardness…they believed large-scale technologies would marshal scare resource efficiently…" (3) the application of food irradiation seemed an useful solution to food crisis (1957) and decreasing the very high waste level (Prybyla, 1962). (4) the emphasis of peaceful utilisation of atomic energy served well the inward and outward (Krige, 2008) Soviet propaganda.

Under these conditions the regulatory framework of the food irradiation was relatively favourable in Soviet bloc, offering an advancement of application of irradiation technologies, even if these had been in a relatively backward position in relation to western states. A striking example of this is the fact, that however the first commercial irradiation apparatus in the world had begun

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

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to work in Germany, in 1957 the new food law banned the treatment of food with ionising radiation (Diehl, 2002). At the same time, the USSR was the first country, where the irradiation of potato begun to apply, one year before Canada and two before USA (Kuprianoff, 1964).

Another important field of research of food irradiation in former Soviet Union has been the study of irradiation on fish preservation (Биденко, 1958). Irradiation experiments have proven, that 14,700–19,600 Gy is enough to achieve the sterility of the fresh fish, but this irradiation is not enough to inactivate the hormones, that is why there are considerable autolytic processes. There are some changes in taste and odour of meat, but this can be eliminated by culinary technology. As a summary, the shelf-live of fishes can be increased by 0.5–2 month, depending of fish-variety and the temperature of storage (Кардашев and Коржова, 1962).

A striking example of dynamics of acceptance of results of irradiation methods supplied the disinfection of grain by ionisation. In the USA and Turkey there had been constructed some sophisticated apparats soon in sixties, but the had not been working as commercial. The first such apparat had been constructed in USSR in 1980 and had begun to work in 1983. It is based on Co^{60}, the two electron-accelerators had been built in the USSR, with a capacity of 20 kW, for 1.4 MeV. The dosage had been 200–400 Gy, with a capacity of 400 t/h grain (Boisseau, 1990).

In Hungary, the first researcher of food irradiation has been Károly Vas (1919–1981). Before "closing of the iron curtain", in 1947 had been able to travel to a study tour to visit the leading centres of food research US (Michigan State University, University of California) as well as in the United Kingdom (University of Cambridge). In these centres he has acknowledged with complex approach of that-time leading food scientists in technology development of food preservation, applying a combination of different (chemical, physical and biological methods) and interest of Károly Vas had been focussing on possibilities of increasing of shelf-life by combined methods of food preservation. On this topics he had widely publicised in eminent academic letters (Vas and Ingram, 1949,). This problem has led him to the field of analysis of effects of irradiation of agricultural and food industrial products (Vas et al., 1968). This new, highly innovative field of research has been a prospective discipline for a generation of young scientists, who-under conditions of iron curtain and isolation have tried to join to the mainstream of global food research. Among them József Farkas (1933–2014) has been dedicating all his life and energy to systematic research of irradiation of agricultural products and food. As it can be judged on base of his works, written in foreign languages (Annexure A), he had been a key personality in a wide range of food science and technology (Fig. 1), research of food irradiation had been a leitmotiv of all his academic activity.

The aim of article is to present the influence of key food researchers in development of scientific foundations of food irradiation in Europe, and the diffusion of knowledge in food irradiation research as well as the interconnection between food irradiation research and food research in general by latest methods of scientometrics, applying the citation analysis, network analysis as well as science mapping.

2. Materials and methods

As a preliminary investigation, we have tried to determine the general, long-range trend of development of food irradiation science, based on number of papers, published in this field. A long-range longitudinal analysis of literature of a given field of science is a rather hard task, because (1) just a few electronic database try to cower a relatively long period, (2) there is a rapid proliferation

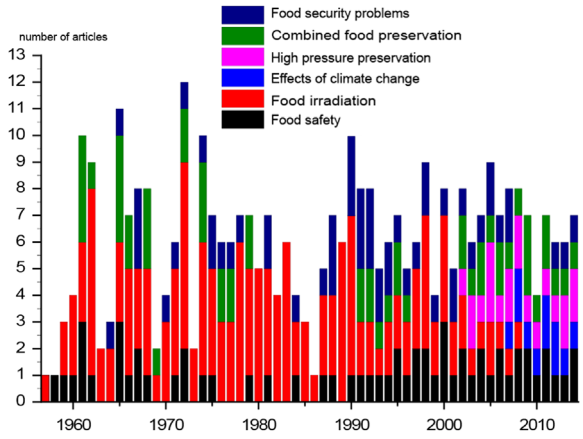

Fig. 1. Scientific articles of József Farkas according to main topics of his publications.

of academic journals and another publication possibilities; (3) the appearance of earlier academic papers in electronic databases is relatively less complete. We have applied two electronic databases for this purpose: the "google scholar" and the "Scopus" databases, and collected the results in different years to search keywords: irradiation and food. Of course, we knew it very well that the results are very far to be exhaustive, but in our opinion can be applied as a proxy of dynamics of level of interest towards the food irradiation problem.

In first step, we have collected scientific works of professor Farkas on base of Web of Science (hereinafter: WoS) system of Institute for Scientific Information (ISI, now part of Thomson Reuters). However there are some arguments for application of its most important concurrent, Scopus of Reed Elsevier (Meho and Yang, 2007). Archambault et al. (2009) had been proven an extremely high correlation between the "performance" of these two databases based on number of papers and number of citations, largely independently of the field of sciences. The rigorous, systematic analysis of academic publications had begun just some decades ago (Leydesdorff, 1998), that's why the time-horizon in our research begun from 1975, because the WoS system (like another citation-retrieval system) is not able to offer reliable results from an earlier period. In this way we had been able to analyse a more than four-decade long period. Based on WoS we have been able to identify 92 academic works of professor Farkas. In next step we have selected such works, which had been focussing on food irradiation problem. This subset of publications consists of 62 elements. Hereinafter we call this set as Corpus No. 1.

In second step we identified those publications in WoS which cite the works of professor Farkas, focusing on food irradiation. Some years ago this task had been a relatively easy one, and some software had been developed to analysis of these pieces of information (e.g. HistCite (Garfield, 2009) and Sci2 (Börner, 2009)) but recently WoS has changed its searching and downloading possibilities, and there exist not a direct way to assign the citing publications to source publications. Using the citation analysis option provided by WoS, we retrieved the set of citing documents, that is, documents referencing any publication of Farkas belonging to Corpus No. 1. This collection, representing the impact of Corpus 1. has been called Corpus No. 2., from which we extracted the author names to obtain the collection of scholars influenced by the works of Farkas. This search yielded more than 1900 authors, but we had to experience, that there had been a considerable number of duplications of citing authors. This is a general problem of scientometric research (Sweetland, 1989; Folly et al., 1981) The names of authors have been duplicated due to different

transcription of names, using non-Latin alphabet (e.g. Arabic, Chinese, Russian, Bulgarian) and differences in order of given names, changing of names of authors (e.g. due to marriage) as well as misspelling of names. Number of citing publications had been 688 up to 15.01.2016. This set had been called as Corpus No. 2.

To examine the scope of scientific impact we used the set of citing publications (Corpus No. 2). To find those research fields which were influenced by Corpus No. 1 we have calculated the frequency distribution of different fields of science in Corpus No. 2. There are different categorization practices of scientific research, but in opinion of Leydesdorff and Bornmann (2015) the Web of Science "subject categories (WCs) has become and established ("best") practice in evaluative bibliometrics." That is why we have applied this categorization system. The frequency distribution of citing publications according to WCs has been projected distribution on the base map of WoS Subject Categories (SCs). This tool is a two-dimensional overlay map, which has been developed by Leydesdorff and Rafols (2009) for visually depicting the research within the sciences by representing the cognitive proximity of SCs' within the science system. There are numerous another science maps, but the different maps show a high level of robustness (Klavans and Boyack, 2006). In process of visualization of position of different citing authors, we have been applying the OECD Research Areas to group WCs into broader disciplines. To better understand the influence of Farkas on academic publications and uncover the hidden structure of scholars, who cited his works, we have used the modularity detection algorithm of Gephi on the co-authorship network (Green et al., 2015).

3. Results and discussion

Analysing the change of importance of food irradiation topics in academic literature, it is obvious, that József Farkas academic activity has been spanned a long and very important period of development of this, exponentially developing discipline. When the first publications of József Farkas have appeared on this topics, there had been published just a few papers on this topics in a year. At the end of his activity, on average much more papers have been published daily, than in his young age yearly (Figs. 2 and 3).

Analysing the distribution of citing papers according to different SCs', projected on science map, it is obvious, that his scope of influence went far beyond the food science and technology (Fig. 4). The construction of science map is based on principles of

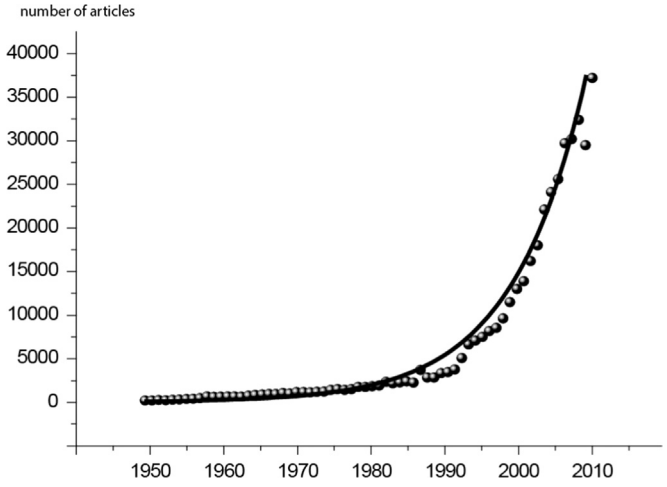

Fig. 2. Number of articles, published on food irradiation according to scholar.google.com and its approximation by equation $y=(3.40658E\text{-}77)e^{(0.09261t)}$ equation ($r^2=0.987$).

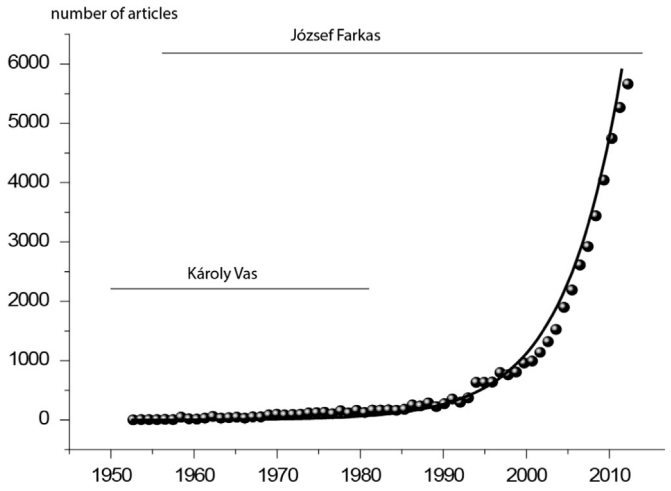

Fig. 3. Number of articles, published on food irradiation according to *Scopus* system and its approximation by equation $y=e^{(-267.853+0.1372t)}$ equation ($r^2=0.995$), with indication of professional activity of Károly Vas and József Farkas.

multidimensional scaling (Kruskal, 1964; Zilinskas, 2015) that is why the interpretation of dimensions are rather arbitrary and leaves room for a wide range of subjective judgements. The ordinate of the graph can be interpreted, as the natural science-versus social sciences dimension, abscise as the engineering science vs. health and medical science dimension.

Analysing the map of influence of Farkas work, a considerable number of citing articles had been categorized into field of natural as well as medical and health sciences. There is a relatively tight connection between the natural sciences and engineering and technology sciences but the "non-and medical as well as health sciences show a considerable distance. This fact highlights the role of activity of Farkas as a "bridge" between these fields of science. Put in another way: work of Farkas (and in a more general concept: the results, which had been achieved by study of food irradiation in the last decades) has been a measurable contribution to development of both fields of science. It is a relatively rare phenomenon, that the works of a food scientists are cited by papers in field of social sciences and humanities. In case of publications of Farkas we can detect a considerable number of citations from these fields. This can be explained by high level of interest of the wider scientific community towards the food irradiation and by holistic approach of Farkas, who has been among the first scientists, who recognized the importance of social acceptance of irradiation, as a food preservation technology in its proliferation.

To identify those groups of researchers who were influenced by Corpus No. 1 we have created a co-authorship network of citing authors. In this network authors who cite J. Farkas are represented by nodes and co-authorship between these authors are represented by edges. We used a community detection algorithm (Blondel et al., 2008) to map cohesive groups of authors that have been influenced by works of Farkas (Fig. 4). In this case there is even lesser possibility to interpret the dimensions, our aim is just to visualise the different authors, using the results of Farkas and/or his team in their work. Influence of J. Farkas on food science and technology development in last decades is well characterized by the fact, that more than 1902 different authors had been citing his works according to WoS. Analysing the community it can be stated, that there is a relatively high level of cohesion between scientists, who work in fields, relevant from point of view of activity of professor Farkas: the number of citations between different authors was 4965. The co-author relations between citing authors have been depicted by edges. The thickness of edges is approximatively proportional by number of co-authorships. At the same

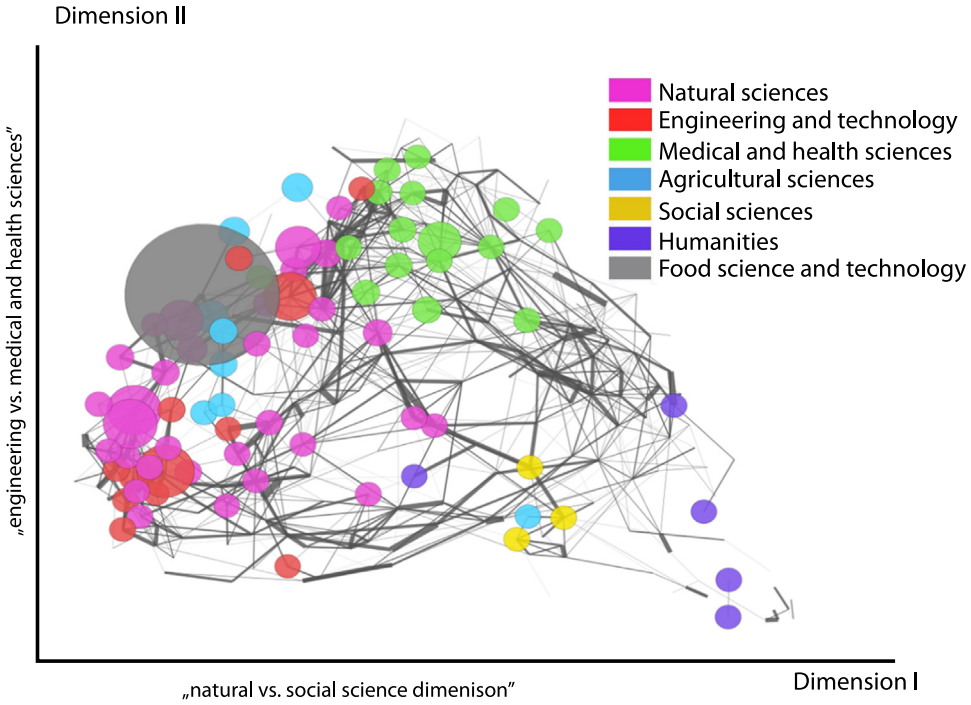

Fig. 4. Communities of actors, citing the works of József Farkas. The size of circles is proportional to author's frequency.

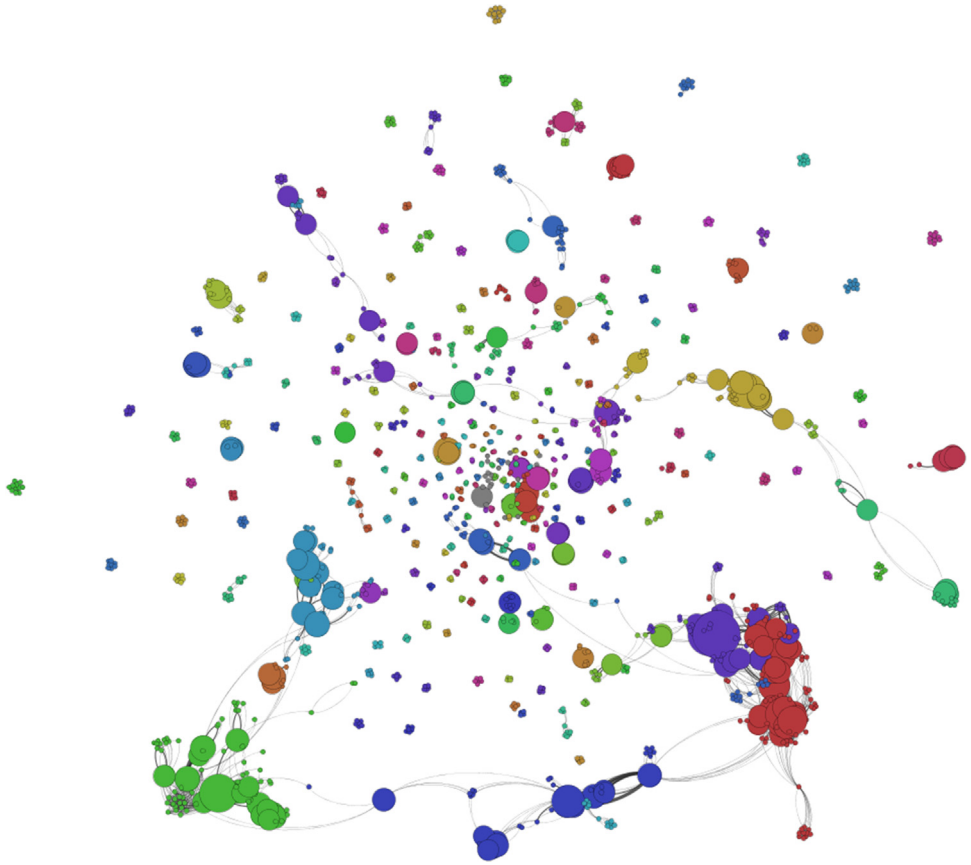

Fig. 5. Distribution of citing papers (Corpus 2) of works of Farkas (the area of circles is proportional with number of citing papers from the given field of science, colour code is the same as in Fig. 4). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

time there are some more "lonely" authors, who cite the works of Farkas just in one or two time. A possible explanation of this phenomenon is that Farkas work are very tightly connected to food preservation in third world. The authors from these countries often do not have the necessary material and intellectual infrastructure (may be that in their countries they are the only academic man in field of food irradiation) to be present in the international academic scene (Fig. 5).

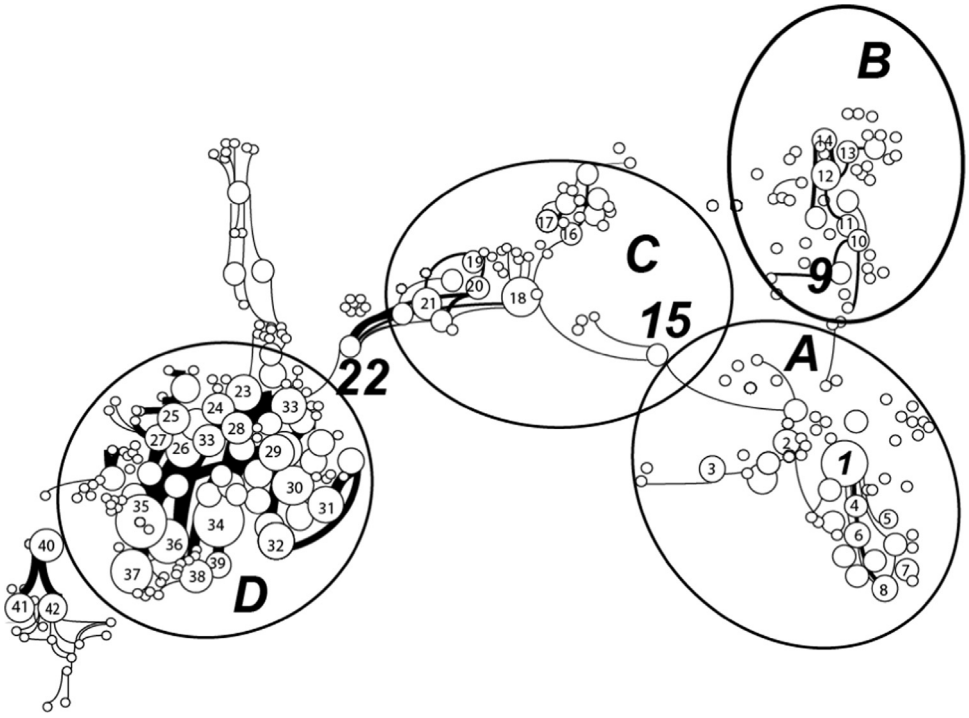

Fig. 6. Giant components of authors, citing the works of Farkas. Józef Farkas and key ("bridge") personalities are highlighted, Legend: 1. Farkas, J., 2. Bhat, R., 3. Shridhar, KR., 4. Lebovics, V., 5. Ehlermann, D., 6. Andrássy, E., 7. Balla, Cs., 8. Nemeth, Cs., 9. Thomas, P., 10. Chawla, SP., 11. Kamat, A., 12. Sharma, A., 13. Nair MN., 14. Kanat, SR., 15. Delincee, H., 16. Ferreira, CFR., 17. Barreira, JCM., 18. Villavicenco, A., 19. Fanaro, GB., 20. Felincee, H., 21. Araujo, MM., 22. Marchioni, E., 23. Byun, MV., 24. Kim, JH., 25. Lee, JV., 26. Han, IJ, 27. Choi, GH., 28. Kim, JG., 29. Jo, C., 30. Ahn, BH., 31. Ju, M., 32. Lee, EJ., 33. Han, RX., 34, Kwon, JH., 35. Ahn, JJ., 36. Kim, GR., 37. Akram, A., 38. Ryu, S., 39. Kim, D., 40. Morreira, AVB., 41. Barros, L., 42. Raul, F.

In identifying cohesive subcommunities of scholars, we obtained the "giant" component of the network, using the same notation as above (Fig. 6). The main component has 404 nodes and 1758 edges. The most relevant authors' name was plotted on the network. These authors' frequency was higher than 5. To improve the interpretability of Fig. 5 we have indicated the most important giant components (modules or clusters) by Latin letters.

Analysing the figure it is very interesting to see, that – notwithstanding the widely accepted theory of globalisation of the sciences (Frenken et al., 2009) there are considerable, spatially separable sub-networks between scientists. This fact supports the general citation analysis results of numerous research, e.g. Hoekman et al. (2010), Pan et al. (2012).

In component A there are mainly European food scientists. A considerable number of them have been long-range cooperation with professor Farkas. Here can be found the overwhelming majority of Hungarian scientists, out of 92 members of this community 32 are Hungarian. This fact highlights one of the most important problems of Hungarian food science: its relative disjunctiveness from mainstream of the "mainstream" of world science.

An important cluster of authors, citing the works of Farkas (component B) is dominated by authors, who work in India (Thomas, Kamat, Sharma, Chawla), or who have analysed the possibilities of application of irradiation technology in developing world. This fact highlight the importance of this technology for food logistics of this subcontinent (Kume et al., 2009) and the results of efforts of different international agencies (e.g. IAEA, FAO) to proliferate the food irradiation science and technology.

Cluster C is dominated by researchers from Brazil and another member states of Latin America.

Cluster D is the largest cluster. This one consist of 110 authors, mainly from Korea, Japan and the US.

4. Conclusions

Our analysis has been proven, that modern, multivariable methods could play an extremely important role in understanding the formation of networks between scientists and different academic schools, that's why its application should be encouraged in a wide array of fields. This methodology is capable to better understand and evaluate the place and role of personalities and academic schools in development of different disciplines.

As a summary it can be stated, that the importance of works of professor József Farkas is reflected not only on base of different fields of sciences, but also in geographic terms. As a single person, József Farkas has been essential in field of food irradiation. His result had been contributed to proliferation and deepening of knowledge level of scientific community on effect of irradiation on food.

On base of scientometric analysis of works of József Farkas it can be proven, that he has made a very important contribution of development of food irradiation science. His activity has been a real bridge between different groups of academic fields, scientists, as well as developed and developing countries, contributing not just to enhancement of our knowledge, but also for the proliferation of this path-breaking technology.

Annexure A

List of publications in foreign languages
József Farkas

Vas, K., Farkas, J., Application of some combined treatments to inhibit microorganisms in fruit juice. *Annales de l'Institut Pasteur de Lille* 209–216, 1960.

Vas, K., Farkas, J., Kiss, I. (1961): Über die Wirkung ionisierender Strahlen auf die Farbe und Geschmack von einigen Fruchtsaften.

Die Fruchtsaft-Industrie 9/10., 350–358, 1961.

Vas, K., Farkas, J., Nyekotorüje nyeposzredsztvennüje vozgyejsztvija ionizirujuscsih oblucsenyij na kletku drozzsej [Некоторые непосредственные воздействия ионизирующих облучений на клетку дрожей]. *Mikrobiologija* 436–440, 1961.

Schmidt-Lorenz, W., Farkas, J., Untersuchungen über die Strahlenresistenz einiger psychophiler Bakterien und Hefen vom Seefisch. *Archiv Für Mikrobiologie* 1–12, 1961.

Farkas, J., Kiss, I., Rázga, Z., Vas, K., Versuche zur Beeinflussung der Keimung von Braugerste durch ionosierende Strahlen. *Brauwissenschaft,* 483–491, 1963.

Farkas, J., Kiss, I., Observations on biochemical changes in irradiated spores of Bacillus cereus. *Acta Microbiologica Hungarica*, 12(1) 15–28, 1965.

Farkas, J., Isszledovanije vlijanija tetraciklinovüh szoegyinyenyii pri hvanyenyii pticnüh tel. [Исследование влияния тетрациклиновых соединиий при храненин птичных тел.] *Mikrobiologija* 1., 65–70, 1965.

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Farkas, J., Investigations into the radiation resistance of Tribolium confusum (DUVAL) and Tyrophagus dimidiatus (HERMANN). *Acta Biologica Hungarica* 3., 207–215, 1966.

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Farkas, J., Kiss, I. & Andrassy, E. Reduction of radiation dose requirements of foods by additives, in: Microbiological problems in food preservation by irradiation, Proceedings of a panel, 1966, pp. 123–31, Vienna, IAEA 1968.

Czukor, B., Farkas, J., Kopasz, J., Use of sterilizable Al foils in the preserving industry. *Konzerv-es Paprikaipar*, 146–151, 1969.

Kiss, I., Kálmán, B., Farkas, J., Prolongation of the storage life of pork cuts by irradiation. *Élelmiszertudomány* 1–2., 17–26, 1970.

Varsányi, I., Kiss, I., Farkas, J., Effect of radurisation doses on polypropylene foil. *Acta Alimentaria* 1, 5–12, 1972.

Farkas, J., Dharkar, S. D., Sreenivasan, A. Transportation and storage studies on irradiated Alphonso mangoes. *Acta Alimentaria* 1, 401–410, 1972.

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