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Application of the Traceability Concept Into Food Supply Chains and Networks Design

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Abstract

The paper aims are presenting the concept of food supply chain and networks management and its components applicable in design of modern fresh and processed (frozen) food distribution systems. Introduction of the traceability concept allows analysis of shipments movements and their origin and, as a consequence tracing the movement of food and its components throughout all stages of its production and distribution. The principles of consistency and transparency in data and information exchange among the participants in the food supply chain and networks create conditions for effectivity and efficiency of food supply systems operation securing their safety and quality making full use of the resources thanks to flexibility of reaction to changes occurring in the needs appearing in the market. The use of Information and Communication Technology (ICT) allows identification of the placement in space and time of food products, the sender and the destination within the food chain. In the second part of the paper the main conclusions of an international benchmark study of traceability systems in different supply chains in several countries are presented. The paper concludes with cost-benefits discussion related to issues that need to be taken into consideration when an organisation develops its chain traceability strategy.

Keywords: food supply chain and networks, traceability, globalisation, information and communication technology-ICT, international benchmark study.

Introduction

Acceleration of changes in the food market occurring after Poland's accession to the European Union in 2004 caused its increased variability and fragmentation. The continuous increase of significance of food quality for the buyers of products is a consequence of that. The increase of food quality importance is possible as a consequence of quality management principles having their roots in the principles developed by E. Deming[2]. Food market fragmentation and increase in significance of quality requirements are accompanied by the need to reconstruct the traditional and build modern food supply chains and networks. The principles of that reconstruction are presented below on the results of international benchmark study.

Mega-trends and their influence on the food market

Enlargement of the European Union in May 2004 by ten states boosted the earlier trends concerning supply conditions in the food market in the areas of : economics, demography, social and cultural and legal, as well as technology and natural environment protection [12],[13],[14].

– *in the area of economics* it boosted the client focus and search for effective revenue/cost relations, which can be exemplified by the following phenomena:

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  - defining consistency of food production and distribution systems with clients' expectations;
  - defining revenue/cost solutions concerning quality assurance and health safety systems in food supply chain ,and networks;
  - influence of the Community Law concerning health (General Food Law EU/2002/178) on external competition conditions of enterprises;

- *in the areas of: demography, social and cultural and legal* – the conditions of food production, distribution and trade are influence by:
  - EU and domestic law regulations and regulations of other international institutions;
  - expectations and behaviours of consumers concerning food (exotic foods from cuisines of the entire world);
  - legal regulations and enforcement institutions in the area of food compliance with human health and animal welfare levels as well as: changes in the demographic structure of consumers determined by professional activity of women;
  - increased share of one- and two persons households, ageing of the society, differentiation of its affluence;

- *in the area of natural environment* the operational environment of links in the food supply chains and networks are influenced by:
  - energy and water consumption in food production, distribution and trade;
  - recycling of packaging materials and waste generated during food production, distribution and trade; and
  - development of new bio-packages friendly to the natural environment;

- *in the area of technology conditions* of products and processes, systems of transport and telecommunication design of influence food production and distribution quality and food safety through:
  - compliance with quality standards consistent with national and international legal regulations;
  - systems of management and control of processes and flow of products through the supply chains (of traceability type, HACCP);
  - care for products and information for the public;
  - increased share of genetically modified food and extended shelf life foods in production;
  - new solutions in organization of logistics infrastructure;
  - appearance of network economy and new possibilities in food trade.

The above phenomena lead to increasing variability and fragmentation of food market catering for individualized needs of consumers [10],[12]:
- increased consumption of exotic foods from various cultural areas;
- increased demand for ecological food;
- increased consumption of food through various catering institution away from place of residence, convenient prepared for fast consumption;
- increased demand for functional food of special use with diversified content of fat, vitamins and other nutrients supporting treatment of specific civilisation diseases or preventing them or causing increased demand for food and drinks improving mental or physical fitness of people.

Changes in food quality management systems

Food products quality according to: Baryłko – Piekielna [1] is understood as the: "degree of health, sensory attractiveness and availability in wide consumer and social meaning, important only within the limits of accessibility determined by conditions negative for that product: raw materials, technology and price."[3].

The above mentioned trends in the food market, increased competition and consumer demands cause that quality according to the international ISO 8402:1996 standard is understood as the "set of product characteristics concerning its ability to satisfy the expressed and expected needs". The quality should not be treated as the level of satisfying selected characteristics as a specified level but it is suggested to approve of quality the level of intensity of which is accepted by the client and the market.

Food quality is a multidimensional concept. Luning, Mercelis, Jongen [7] divide the qualitative characteristics of a food product into intrinsic and extrinsic, allowing satisfaction of consumer expectations. The intrinsic characteristics allowing objective measurement of product quality include: health safety and health value of the product, sensory attractiveness and shelf life as well as compliance of product characteristics with the standard and ease of preparation for consumption. The extrinsic quality characteristics of food product are determined by specific characteristics of production system (e.g. acceptable production level of genetically modified food of food preservation processes), influence of environment conditions of food product and its production (use and utilization of used packages) and marketing activities increasing the level of consumer perception (through brand policy, marking method and price).The above mentioned intrinsic and extrinsic characteristics of food product quality determine its position in the logistics chain and, as a consequence, determine organization of its control or creating conditions for its assurance.

Concept and characteristic of Food Supply Chain Network – FSCN

Fragmentation of food market, in line with the above-presented principles of multidimensional analysis, is accompanied by restructuring of traditional food distribution channels into modern supply chains and networks. The Food Supply Chain Network - FSCN is understood as a direct network of actors (participants), who cooperate with one another in supplying products to the consumers by Lazzarini, Chaddad, Cook [6]. Those entities can play different roles in different chains (FSCN) within which the vertical and horizontal partner relations between them change dynamically. That allows identification of two types of food supply networks Zuurbier, Trienekens, Ziggers [18]:

1. FSCN for fresh agricultural products (fruit, vegetables, flowers) involving the growers, auctions, wholesalers (distribution centres) exporters and importers, retailers, specialized shops, their suppliers and services provided. The basic processes cover purchase, conditioning, packaging, transport and trade in those products;
2. FSCN for processed food products (packaged processed meat products, snacks, deserts, frozen foods). In those chains agricultural products are used as raw materials for production of products for consumption representing high level of processing. Preservation and conditioning extends the shelf life of agricultural and food products.

Food Supply Chain Networks (FSCN) are characterized by 4 components allowing analysing and reconstructing them. Those are by van der Vorst, Beulens, van Beek [16]:

– network structure that represents key actors (participants) and their mutual relations;
– chain of business processes defining the sets of business activities allowing production of products possessing particular characteristics, offering specified services (Lambert, Cooper, 2000);
– management of supply chains and networks, that describe management and coordination of supply network structure facilitating performance of tasks by participants through appropriate actions and use of their resources;
– supply chains resources used for production of products and supplying them to clients covering people, equipment, information systems and their infrastructure. Each process is identified in the network to use it for reconstruction of the FSCN.

Application of the traceability concept into information and communication technologies in food supply chain networks management

Management of Food Supply Chain Networks (FSCN) is linked to development of (Information & Communication Technology – ICT) defined as the technically available resources, knowledge and attitudes allowing organization of their application for performance of business and communication activities through by van der Vorst, Beulens, van Beek [16]:
– more effective and efficient use of the resources by their users;
– development and application of ICT technology for better management of supply chain and network and the individual links within them;
– development and application of ICT tools and infrastructure for building the business strategy within the food supply chains and networks.

Application of information technology in FSCN is implemented through:
– data accumulated in databases, which is necessary for business processes management based not only on local information networks but, first of all, on the Internet. Those databases contain information on the number of producers, providing the clients with information on products, processes and cooperation with other food supply chain and network partners;
– formulating a consistent system for coding and information transfer allowing automation of communication among business partners within the FSCN on the basis of the international standard EAN-UCC (European Article Number Association/Uniform Code Council), which was transformed into the Global Standard GS1 in 2005;
– development of technical infrastructure encompassing appropriate computer networks and software and personnel employed, allowing use of databases contents and effective communication within the food supply chain network (FSCN);
– defining organizational infrastructure covering all internal activities of the organization and the FSCN and separating the entity dealing with making those resources available and, as a consequence, the diffusion of innovation based ICT along the supply chain.

The traceability concept is the key to effective and efficient use of information technologies in food supply chain network management. Successful food policy defines the role of traceability for animal feeds and food components by implementation of appropriate procedures. Directive of the European Commission EC/178/2002 determines the importance of traceability as the instrument to warranty food safety. That Directive specifies that as of January 1, 2005, the producers must identify the suppliers of their raw materials and consumers of their final products on the basis of transactions. The basis of traceability information is the possibility

of determining the source of action of specific structure and places where other actions possessing corresponding structure are positioned in the supply chain. That is why tracking products movement and tracing their origin represent the concept of traceability.

Among many other definitions, two definitions of traceability deserve consideration by Trienekens & van der Vorst [14]. Those are:
– the ability to track the movement of food, animal feeds or other components that could become components of food throughout all stages of production and distribution (EC/178/2002); and
– traceability is the quality management system ability to track the history, application or identification of the object or activity or similar objects or activities thanks to their identification (ISO 8402).

Traceability can be defined in the narrow or wide meaning of the term. In the narrow meaning it allows people to determine where the products are at any moment of time. The real time tracking function allows identifying the history of not only the product but also of its components as well as the use of every final product. In the wide meaning traceability means that information on products and processes of producing them can be used for optimization and control of processes within and between individual links of the supply chain offering the possibility of decreasing costs, increasing productivity and assuring quality.

Traceability of information has a separate importance for organization and supply chain. At the enterprise level it allows supplying information on location of products and their history. At the supply chain level, it allows determining not only information on product location, but also information on products origin.

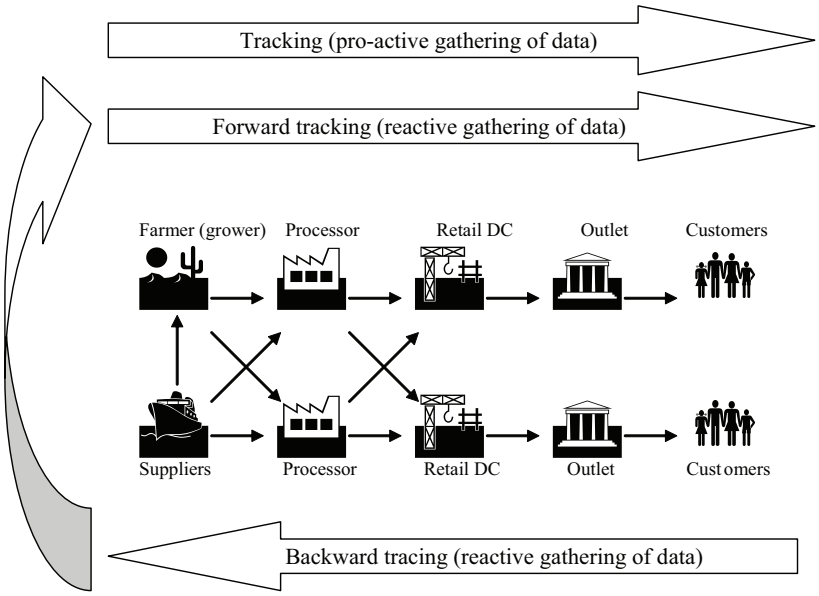

Fig. 1. Tracking and tracing the movement of products and their origin in the chains Source: J. Trienekens & J. van der Vorst: Traceability in Food Supply Chains in: Safety Agri-Food Chain, Wageningen Academic Publishers, 2006, p.449.

As a consequence of participation of many actors (industry, government-administration institutions, consumers) in the chain, it is of particular importance for entrepreneurs participating in the supply chain to be able to guaranty the composition and genesis of their products through building the information system allowing cooperation in supply chain. Information system for traceability in case of a supply chain is presented in Figure1.It allows:
identification of production and products within the supply chain. The purpose of identification is the obtaining data concerning individual activities using codes (barcodes, lab);
tracking movement of objects allowing locating them along all their path within the supply chain;
traceability of movement of objects within the food chain allows identifying their composition at individual stages of the supply chain. In the lower part of the supply chain the purpose of tracing is to determine the history of the object and sources of problems causing their damage. In the upper part of the chain the purpose of tracking is to determine location of products made using, e.g. contaminated raw materials.

The concept of traceability offers benefits for supply chain participants, i.e. consumers, industry and government administration institutions that are presented in Table 1 below.

Table 1. Benefits of traceability concept for supply chain participants

Consumers	Industry	Government Administration Institutions
Maintaining food safety thanks to the system of returns Allowing avoidance of foods and food components causing civilisation diseases.	Protecting public health through food withdrawal procedures. Protection against adulterations that cannot be detected through analyses. Help in protecting human and animal health in situations of threats.	Compliance with applicable legal regulations. Have the right to withdraw products from sale. Possibility of diagnosing production conditions assuring quality of food in the market and confidence of consumers.

Source: J. Trienekens & J. van der Vorst: Traceability in Food Supply Chains in: Safety in the Agri-Food Chain, Wageningen Academic Publishers, 2006. p. 447.

Principles of information traceability system organization in food chains and networks

The implementation of information traceability in food supply chain networks involves, among others, organization of traceability of data obtained from various sources. Such data covers Sokołowski [11]:
transaction data allowing management of information system covering: identification of transaction itself and measures for assessment of the transaction;
product identification data in the form of the Global Trade Item Number – GTIN;
data on transaction participants in the supply chain using the Global Location Number-GLN.

Besides data traceability, consistency and transparency of data exchange among participants in the FSCN is the condition of traceability for their information systems. This means that

exchange of information between participants in the FSCN is done according to a specified sequence. It starts from data registration and collection through design of data analysis model allowing data processing as the base for taking decisions by FSCN participants. The Global Data Synchronization - GDS model offers the standard of information allowing assurance of compatibility of the basic data in products and services of business partners. The Electronic Data Interchange – EDI system based on the Internet allows using the Global Standard GS1.

Current practices in Food Supply Chains to support traceability of food products. Benchmark Study

The research investigated supply chains of: meat, dairy, fruit & vegetables, and grain/bread products from :feed supplier - via - primary producers – processing industry, - and retailers-to customers. in seven countries: Australia, Germany, The Netherlands, Spain, Sweden , the United Kingdom, and the USA. were presented by Van der Vorst , [17]

The research was based on the conceptual model presented in Figure 2.

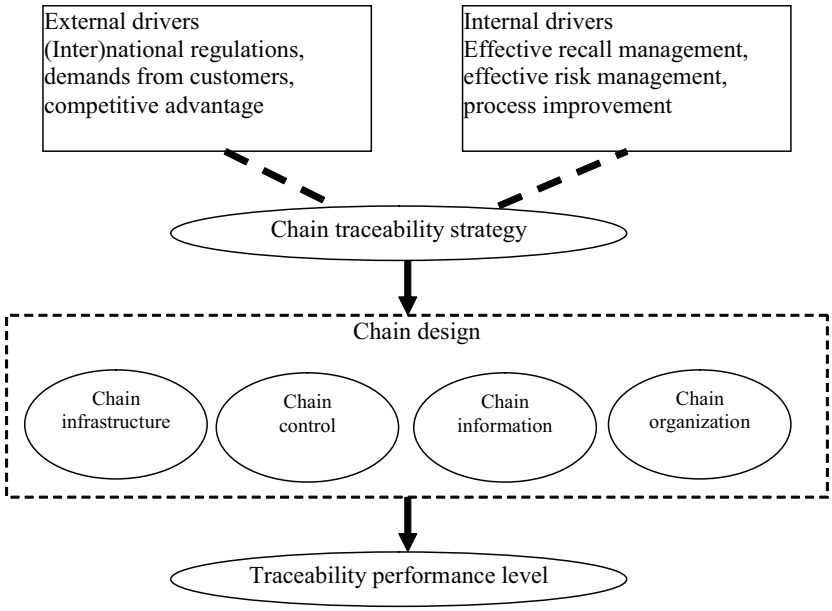

Fig. 2. Conceptual model to evaluate chain strategies.

Source: van der Vorst J.,G.,A.,J.,: *Performance Levels in Food Traceability and the impact on Chain Design:* Results of an International Benchmark Study, in :Dynamics of Chain & Networks (eds. H.J.Bremmers, S.W.F.Omta, J.H.Trienekens, E.F.M.Wubben), Proceedings of 6 International Conference on Chain & Network Management and Food Industry, Wageningen Academic Publ., Ede May 2006,pp.178.

The model proposed that the performance concerning traceability in food supply chains was based on the following elements:

– the external & internal drivers for traceability;
– the strategy of the company/supply chain conserning food safety & traceability;
– specificity in the design of the supply chain (physical structure, planning &control of processes, degree of chain transparency & use of ICT, organisation of supply chains);
– current traceability performance.

To compare the characteristics between supply chains on the use of ICT for traceability for food safety were needed dates collected by electronic questionnaire. In research were obtained 49 questionnaires divided between different supply chains & countries (meat:19,dairy:11,fruit & vegetables :11,grain/bread:8).The research considered a qualitative benchmark study that compares best practices of the four supply chains in seven countries. Characteristics of the supply chains were presented in the following table 2.

Table 2. Characteristics of the supply chains & the best practices

	Meat	Dairy	Fruit & Vegetables	Grain-bread
Characteristics of the supply chains	Long and complex chain. Development towards integration. Much attention to traceability	Long in general integrated & cont rolled chains. Milk flows makes traceability complicated	Very diverse chain structures. Development to-wards retail integration& branding	Complex product flows(commodity) GMO issue gets more attention for food safety
Incentives for working on traceability	Law, customer demands, branding	Prevention, focus quality	Law, customer demands, branding	Law, (GMO-issues) few branding initiatives
Best Practice	Integrated chain from feed supplier to retail	Cooperative chain from farmers to processors	Coordinated chain with certified sup-pliers & contra-ctual relation ship with retail	Chain with preferred certified suppliers with contractual relationship
Chain performance traceability	Full chain within 24 h & individual animal	Within 24 h. & to large number of farms	Within few hours to specific harvest grower	Within 24 h. & to number of farmers
Use of ICT	Ear labels (some electronics), barcodes (EAN) transponders, DNA identification, central databases, EDI, Internet	No chain systems functional silos, barcodes (EAN). RFID, EDI, Internet	Little use of ICT, functional silos, Customer made software, barcodes (EAN), RFID	Little use of ICT, many customers of single systems, bar codes (batches)
Initiatives for tractability	Many in many countries	Few focus on pre-vention	Many in many countries, focus on product coding	Most initiatives aim at lot separation (GMO)
Conclusions	Many developments More international cooperation& bran ding request	Traceability is not an issue	Development from spot market to chains, more differentiated prepacked products	Development from commodity to specialty (branding)

Source: van der Vorst J.,G.,A.,J.,: Performance Levels in Food Traceability and the impact on Chain Design: Results of an International Benchmark Study, in: Dynamics of Chain & Networks (eds. H.J.Bremmers, S. W. F. Omta, J. H. Trienekens, E. F. M. Wubben), Proceedings of 6 International Conference on Chain & Network Management and Food Industry, Wageningen Academic Publ., Ede May 2006,pp.180.

Impact of Traceability Strategy on Chain Design

The research results have identified following bottlenecks for reliable traceability in food supply chains:

– Indefinite and differentiated performance levels concerning traceability in different supply chains;
– Little economical incentives for traceability. It is unclear what the costs of traceability will be;
– High investments in infrastructure for full traceability;
– Lack of chain organisation and chain transparency;
– Lack of standardisation-information for establishing traceability is registered in all links of the chain.

From the benchmark study we can distinguish three chain strategies of traceability:

1. *Compliance – oriented strategy.* The companies focus on the registration of incoming and going materials and used standard procedures. The chain is a usually a fragmented organization oriented on traceability since each company should individually comply to the demands directed specifically at it. The chain performance at compliance case is measured as a compilation of all individual performances;
2. *Process improvement-oriented strategy:* realized the control of the traceability of products within the own link by means of production integrated measures .Examples of the process oriented strategy are local ICT systems that register all process data;
3. *Market-oriented* (*branding*) *strategy* established a full traceability within the supply chain to achieve competitive advantage. This requires the redesign of processes. The traceability performance is a result of joint effort to design and produce a product. Its need to redesign structure of chain in which individual links works intensively together according to dynamically changed markets.

Which traceability strategy is the best for specific company of supply chains depends on the trade off between costs and benefits, and can differ for each specific product group. (see Figure3) High levels of traceability require investments in: processes, infrastructures, information systems and people relationships.

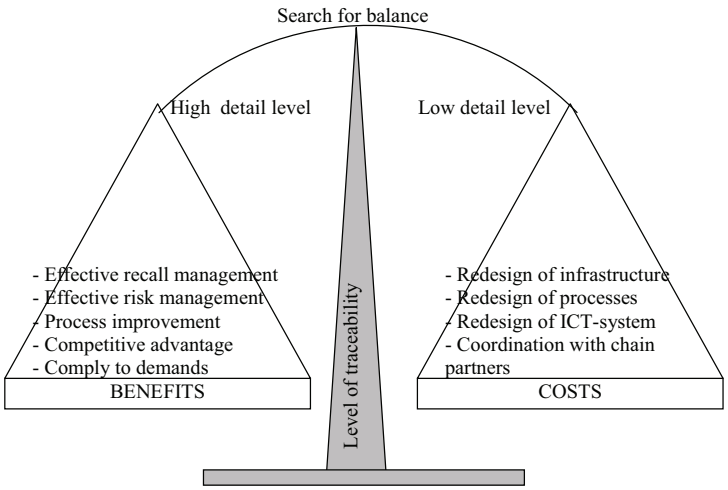

Fig. 3. Cost/benefits trade-off to determine the traceability performance level.

Source: van der Vorst J., G., A., J.,: Performance Levels in Food Traceability and the impact on Chain Design: Results of an International Benchmark Study, in :Dynamics of Chain & Networks (eds. H. J.Bremmers, S. W. F. Omta, J. H. Trienekens, E. F. M. Wubben), Proceedings of 6 International Conference on Chain & Network Management and Food Industry, Wageningen Academic Publ., Ede May 2006, pp.182.

Conclusions

Application of information technologies in FSCN management to choose the appropriate level of chain traceability can be presented in the following way:

– that application focuses on cost effectiveness with increasing attention devoted to generating profit and using the available resources;
– increased importance of food safety and quality by choosing appropriate traceability strategy;
– use of process and system approach and possibility of continuous improvement in FSCN restructuring processes;
– increasing the role of international cooperation as a consequence of possibility of making flexible choice of partners;
– increased use of modern information collection and processing methods-applied in GS1;
– consolidation of products and information flows within organizations, between them and within the FSCN.

Bibliography

1. Baryłko-Piekielna N.,1975: *Zarys analizy sensorycznej* [Sensory Analysis Outline] WNT, Warsaw.
2. Deming W.,E.,1993: *The New Economics for Industry,Government Education*, MIT, Center for Advanced Engineering Studies, Cambridge MA.
3. Hamrol A.,2005: *Zarządzanie jakością z przykładami*, [Quality Management with Examples) WN PWN, Warszawa.
4. Jongen W. M. F., Meulenberg M. T. G., (editors), 2005: *Innovation in Agri-Food Systems*, Wageningen Academic Publishers, Wageningen.
5. Lambert D., Cooper M. C., 2000: *Issues in Supply Chain Management*, Industrial Marketing Management 29, pp. 65-83.
6. Lazzarini S. G., Chaddad F. R., Cook M. L., 2001: *Integrating Supply Chain & Network Analysis*, Study of Netchains, Journal on Chain & Network Science,1, pp. 7–22.
7. Luning P. A.,Marcelis W. J., Jongen W. M. F., 2002: *Food Quality Management. A Techno-Managerial Approach*, Wageningen Pers, Wageningen.
8. Luning P. A., Devlieighere F., Verhe R., (editors), 2006: *Safety in the Agri-Food Chain*, Wageningen Academic Publishers, Wageningen.
9. Ross D. F., 2003: *Introduction to e-Supply Chain Management*, St. Lucie Press, Bocca Ration, London, New York, Washington D. C.
10. Schaafsma G., Kok F. J., 2005: *Nutritional Aspects of Food Innovations: a Focus on Functional Foods*, in: *Innovation in Agri-Food Systems* (editors W. M. F. Jongen, M. T. G. Meulenberg), Academic Publishers, Wageningen.
11. Sokołowski G. 2005: *„Traceability"– nowe wymagania prawa unijnego*, [Traceability – New Requirements of European Union Law] *Przemysł Spożywczy* [Food Industry], No. 7, pp. 8–9.
12. Szymanowski W., 2004: *Przedsiębiorstwo przemysłu spożywczego jako zintegrowany system zarządzania jakością* [Enterprise in the Food Industry as an Integrated System of Quality Management] in: *Wybrane problemy nauki o żywieniu człowieka u progu XXI wieku* [Selected Problems of Human Nutritions in XXI], (scientific editors: Brzozowska A., Gutkowska K.), Wydawnictwo SGGW, Warsaw, pp. 485–489.
13. Szymanowski W., 2006.: *Modelowanie projektowania łańcuchów dostaw* [Designing of Food Supply chain], Ekonomika i Organizacja Przedsiębiorstw, no. 1, pp. 17–27.

14. Szymanowski W., 2007: *Application of Information Technologies in Food Supply Chain and Networks Management in the Environment of Food Market Globalization – Traceability Concept*, Olsztyn Economic Journal nr. 2, pp. 88–100.
15. Trienekens J.,& van der Vorst J., 2006.: *Traceability in Food Supply Chains in: Safety in the AgriFood Chain*, Wageningen Academic Publishers, Wageningen.
16. Van Boekel M .A. J. S., 2005.: *Technological Innovation in the Food Industry: Product Design in: Innovation in Agri-Food Systems* (editor W. M. F. Jongen, M. T. G. Meulenberg), Wageningen Academic Publishers, Wageningen.
17. Van der Vorst, J. Beulens A. and van Beek P., 2005,: *Innovations in Logistics & ICT in Food Supply Chain Networks in: Innovation in Agri-Food Systems* (editor W. M. F.Jongen, M. T. G. Meulenberg), Wageningen Academic Publ. Wageningen.
18. Van der Vorst J., G., A., J.,: *Performance Levels in Food Traceability and the impact on Chain Design: Results of an International Benchmark Study*, in :Dynamics of Chain & Networks (eds. H. J. Bremmers, S. W. F. Omta, J. H. Trienekens, E. F .M. Wubben), Proceedings of 6 International Conference on Chain & Network Management and Food Industry, Wageningen Academic Publ., Ede., May 2006.