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APPLICATION OF INFORMATION TECHNOLOGIES IN FOOD SUPPLY CHAINS AND NETWORKS MANAGEMENT IN THE ENVIRONMENT OF FOOD MARKET GLOBALISATION – TRACEABILITY CONCEPT

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A b s t r a c t

The paper aims at 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 he 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. Global standardization of barcodes allows identification of the placement in space and time of food products, the sender and the destination within the food chain. The use of Information and Communication Technology (ICT) serves that purpose. 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.

WYKORZYSTANIE TECHNOLOGII INFORMACYJNYCH DO ZARZĄDZANIA ŁAŃCUCHAMI I SIECIAMI DOSTAW W WARUNKACH GLOBALIZACJI RYNKU ŻYWNOŚCI- KONCEPCJA TRACEABILITY

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S ł o w a k l u c z o w e: łańcuch i sieci dostaw żywności, globalizacja rynku żywności, technologie informacyjno-komunikacyjne.

Abstrakt

Celem artykułu jest przedstawienie koncepcji *zarządzania łańcuchami i sieciami dostaw żywności,* jej składowych, znajdujących zastosowanie w budowie nowoczesnych systemów dystrybucji żywności świeżej i przetworzonej (mrożonej). Wprowadzenie koncepcji *treceability* umożliwia analizę ruchu ładunków i ich pochodzenia, a dzięki temu śledzenia ruchu żywności i ich składników przez wszystkie fazy jej produkcji i dystrybucji. Ujednolicenie w skali globalnej systemów kodów kreskowych pozwala zidentyfikować miejsce w przestrzeni i w czasie produktu żywnościowego, jego nadawcy i przeznaczenia w łańcuchu żywnościowym. Temu celowi służy wykorzystanie technologii informacyjnych i komunikacyjnych (*Information & Comunication Technology – ICT*). Przedstawione następnie zasady spójności i przezroczystości wymiany danych i informacji między uczestnikami łańcuchów i sieci dostaw stwarzają warunki efektywności i skuteczności funkcjonowania systemów dostaw żywności, zapewniając im bezpieczeństwo i jakość, z pełnym wykorzystaniem zasobów, dzięki zachowaniu elastyczności reakcji na zmiany zachodzące w potrzebach pojawiających się na rynku.

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. 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.

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 (SZYMANOWSKI 2004, 2006, TRIENEKENS VAN DER VORST 2006):

- 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:
  - 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 chains 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 influenced 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 he 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 design of products and processes, systems of transport and telecommunication 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, as well as:
  - 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 by means of (SZYMANOWSKI 2004, SCHAAFSMA, KOK 2005):

- increased consumption of exotic foods from various cultural areas;
- increased demand for ecological food (KŁOSIEWICZ-GÓRECKA 2003);
- 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 1975) 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".

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 (2002) 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.

Food quality management is based on 8 quality management principles published in ISO 9001-2000 standard applied at enterprise levels stemming from the principles developed by E. Deming covering, among other things (HAMROL 2005, LUNING, DEVLIEGHERE, VERHE 2006, SZYMANOWSKI 2006):

– *client focus (principle 1)* i.e. taking actions consistent with client;s quality expectations through identification of internal and external clients the relations with whom are based on a variety of contractual arrangements;
– *leadership (principle 2)* including creating conditions for drawing from organization resources, in particular *commitment of employees (principle 3)* in achievement of quality targets. Food production enterprise is characterized by high quality management system dynamics with a changing timeframe and as a consequence increased level of uncertainty concerning the

decisions taken. The timeframe of market decisions ranges from 0.5 to 2 years while the timeframe of technological innovation decisions is 2-5 years; he timeframe of changes in raw materials base using genetic engineering is 5-15 years (VAN BOEKEL 2005);

- *approach: process (principle 4*) and *systemic (principle 5).* The process approach means that the organization focuses on processes implemented within it and not on organizational units or functions. *Maps of processes* that make the owner and people involved in preparing them that the performed sequence of interlinked actions represents a correctly formulated logical whole leading to multiplying the added value, are a tool for identification of processes and heir components (sub-processes). The systemic approach to organization management means perception of organization operation results not as a sum of the results of component processes over time and space but the consequence of using the effect of synergy boosting the global effect of activity in absence of partial effects optimisation. In food quality management the systemic approach generates tools for identification of food safety that are components of food quality management;
- *continuous improvement (principle 6)* represents continuous improvement of the quality management system closing the gap between the consumer expectations and the fulfilment of those expectations. The continuous quality improvement model satisfies the conditions of the improvement cycle by E. Deming P-D-C-A (plan, develop, control, implement) describing continuous quality improvement in a systematic way and implemented by ISO 9001-2000 standard;
- *informed decision taking (principle 7)* – is based on systematic data collecting and processing by means of trustworthy methods giving the base for taking decisions, being an inseparable component of information systems for quality management. Quality strategy and policy decisions in a food production company concerning a food product can be divided into (LUNING, MARCELIS, JONGEN 2002):
  1. *strategic decisions* that represent the process of choosing the organization mission, i.e. clients, areas and methods of operation, goals to be achieved within specific time periods and selection of basic resources for achievement of those goals. Definition of the mission determines the choice of the target group of customers and, as a consequence, the choice of products quality level satisfying the requirements of clients, which in turn would determine the quality of long-term decisions concerning concentration of resources on selected measures;
  2. *innovation decisions* determining the choice of products and their characteristics consistent with the mission and strategic goals as well as the future abilities of the company. Those decisions include design of new products, selection of market segments, selection of processes allowing

achievement of the designed characteristics by those products and specification of resources for building the supply chains and distribution channels for finished products; market analysis;

3. *operational decisions* are decisions allowing current achievement of the volume, quality, times and places of deliveries as well as securing means for creating hygienic conditions within which those tasks will be performed;

- *partnership in relations with suppliers (principle 8)* is based on establishing mutual long-term relations with the suppliers. The long-term partnership should be based on the "win-win" strategy the beneficiaries or which are both the suppliers and the producers. The importance of that principle is particularly well marked in production and sale of high quality food. The increase of strategic importance of suppliers selection for food manufacturers is achieved by means of (ROSS 2003):
  – increased time, quality and cost requirements resulting from the principles of cooperation between the supplier and the producer;
  – change in the specific features of the supplies market that is subject to similar changes as the consumer goods market;
  – changes in market infrastructure as a consequence of appearance of new wholesale market institutions, distribution and trade centres;
  – increased demand for quality assurance and control and assuring innovation processes;
  – assuring the implementation of the continuous management processes improvement principle;
  – increased importance of Internet technologies in planning, forecasting and filling the stocks.

Concept and characteristic of Food Supply Chain Network – FSCN

Fragmentation of food market, in line with the above-presented principles of quality management 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 (LAZZARINI, CHADDAD, COOK 2001). 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 1996):

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 (VAN DER VORST, BEULENS, VAN BEEK 2005):

– *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 information and communication technologies in food supply chain networks management. The concept of traceability

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 (VAN DER VORST, BEULENS, VAN BEEK 2005):

– 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 (TRIENEKENS, VAN DER VORST 2006). 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 84022).

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.

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 Figure 1. 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, labels, etc.);
– tracking movement of objects allowing locating them along all their path within the supply chain;

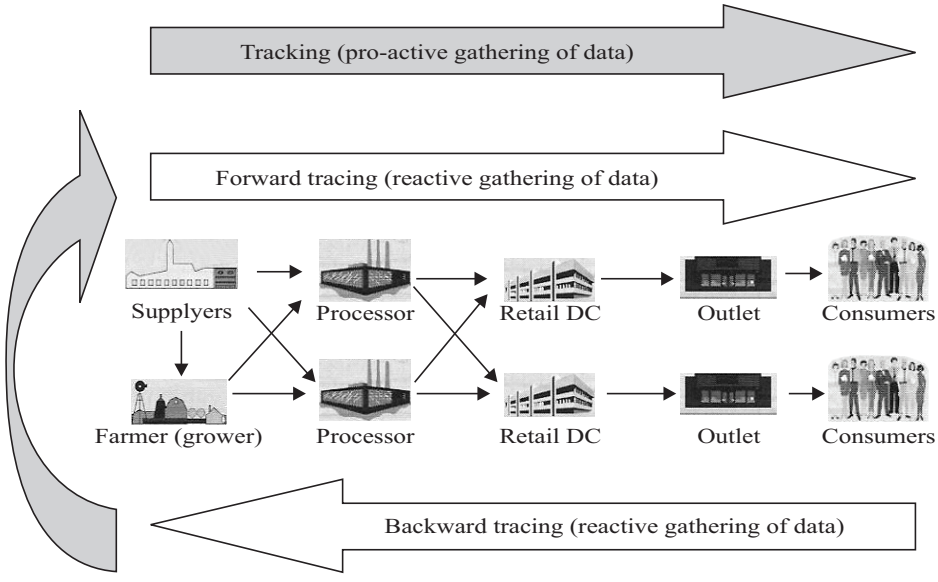

Fig. 1. Tracking and tracing the movement of products and their origin in the supply chain
Source: J. Trienekens & J. van der Vorst: Traceability in Food Supply Chains in: Safety in the Agri-Food Chain, Wageningen Academic Publishers, 2006, p. 449.

– 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 (more on the subject in SOKOŁOWSKI 2005):

– *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.

The above-presented principles of data traceability and information systems allowing management of food supply chain networks FSCN, allow designing the functional classification of information systems applicable to managing them.

We can identify the following types of information systems of FSCN participants:

1. Production Automation Systems of *Digital Control Systems* (DSC) type at the production plant level that allow determining the level of production, stocks and transport tasks;

2. Supervision, Control and Data Collection Systems. Those are systems controlling many production automation systems combined in one whole in real time. They gather detailed information and report information on transactions between those components of FSCN;

3. Systems acting as intermediaries between production performance control systems and the integrated business area systems. Those are *Manufacturing Execution Systems MES.* They support work of operational level managers in drafting schedules, allocation of tasks, for control and monitoring of operational activities;

4. Business area systems include Integrated Enterprise Management Systems such as *ERP (Enterprise Resourcing Planning)* covering taking decisions at the planning and operation levels concerning all major functions in the enterprise. The ERP systems are accompanied by *CRM (Customer Relationship Management) and SCM (Supply Chain Management) type systems as well as TMS (Transport Management Systems) and WMS (Warehouse Management Systems)* type systems. Exchange of information between organizations is done using the EDI system .Traceability is one of the functions increasingly often included in business and executive area systems;

5. At the highest strategic level there are the *MIS (Management Information Systems) and DSS (Decision Support Systems).* Those systems support decisions taken by managers at strategic level while formulating and assessing strategic options for individual organizations and the entire FSCN (Fig. 2).

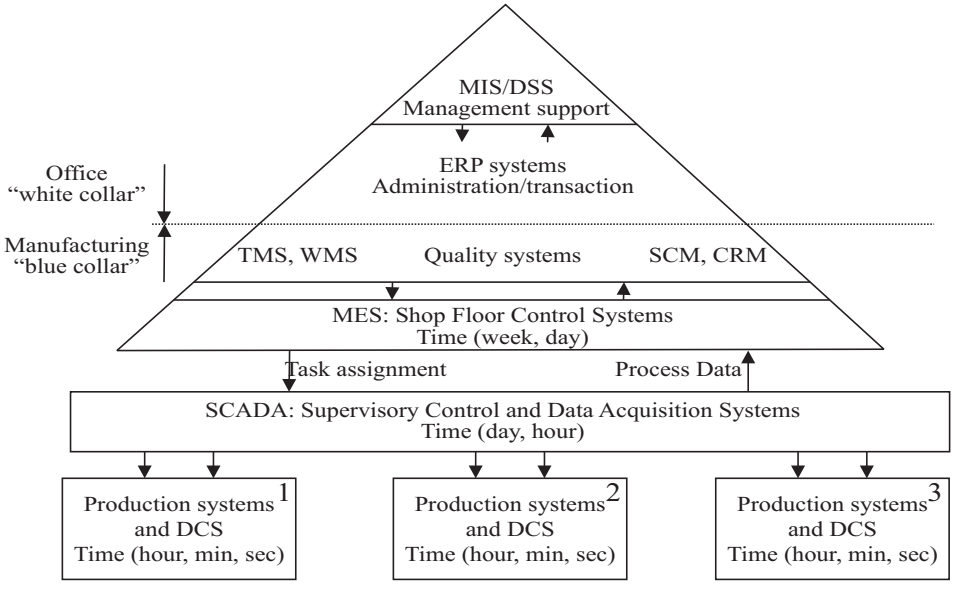

Fig. 2. Types of information systems in supply chain management
Source: J. Van der Vorst, A. Beulens, P. van Beek: Innovations in Logistics & ICT in Food Supply Chain Networks in: Innovation in Agri-Food Systems (editors: W.M.F. Jongen, M.T.G. Meulenberg), Wageningen Academic Publ. 2005, p. 273.

Conclusion

Application of information technologies in FSCN management 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;

– 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;

– consolidation of products and information flows within organizations, between them and within the FSCN.

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