NEW TECHNOLOGY ADOPTION IN FOOD CHAINS: A REVIEW WITH SPECIAL REFERENCE TO GMO APPLICATIONS IN LIVESTOCK PRODUCTION

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ABSTRACT

Recently a growing number of new food technologies has appeared. These technologies aim at improvements with respect to a number of consumers concerns such as food safety, animal welfare and environment. Some of them reduce production costs and therefore diminish prices of final products. Although new technologies can bring substantial benefit, not all of them are readily adopted and accepted. The goal of this paper is to review the technology adoption process along the food chain, so including suppliers, producers, processors and consumers. We focus on GMO in livestock chains. A conceptual framework is proposed along which the literature is discussed.

Keywords: technology adoption, GMO, food chain

1. INTRODUCTION

Recently a growing number of new food technologies has appeared. These technologies, for instance irradiation and biotechnology, aim at improvements with respect to different concerns such as food safety, animal welfare and environment. Some of them reduce production costs and therefore diminish prices of final products. Although new technologies may bring substantial benefit, not all of them are readily adopted and accepted.

Technology adoption and acceptance is a broad process. It can be studied from different perspectives: by categories of adopters or by adoption rates. This paper focuses on technology adoption in food chains and, more specifically, on adoption of GM technology in livestock production chains. Acceptance or adoption of food technologies will depend on their perceived and actual profitability, fixed costs of transition, uncertainty of outcomes, as well as on consumer preferences that may exist with respect to the specific technology. Many studies have been done on technology adoption at the individual farm level or on acceptance at the consumer level. More investigation is needed to study the technology adoption from a chain perspective. The purpose of this paper is to review the available literature on technology adoption from a chain perspective, including suppliers, producers, processors and consumers. We focus on GMO in livestock production chains.

The paper proceeds as follows. In the second section, we outline findings from literature on recent biotechnology developments in plant (feed) and livestock sectors of agriculture. Possible GM applications are discussed by stage of the chain. The third section of the paper introduces the conceptual framework of GM technology adoption in food chains. Finally, we discuss a future outlook for technology adoption analysis.

2. GMO IN LIVESTOCK PRODUCTION CHAINS

2.1 GM crops and animals

There are many definitions of genetically modified organisms (GMO) and genetic engineering (GE). The term "genetic engineering" covers a range of ways of manipulating genetic material. The process of moving genes into a new species and getting them to function is known as genetic modification or engineering. Although each plant variety and each animal is a "genetically modified organism", the term GMO refers to the product or technique, which recombines specific sections of the genetic code from one organism to produce a new plant, animal, or microbe (Gilissen and Nap, 2000).

The majority of current GMOs are micro-organisms. Over 60% of all industrial enzymes produced worldwide, including enzymes used in food production, are produced in genetically modified micro-organisms (Gilissen and Nap, 2000). One of the first commercial examples was the production of the cheese-making enzyme chymosin (Engel, *et al.*, 2002).

Genetic engineering is also already widely spread in crop farming. There is a number of examples of successfully introduced crops such as modified corn, soya or rape, used as ingredients for animal feed.

The term GM animals refers to the animals that were fed by using GM-feed, -enzymes, -feed additives, and -vaccines (Bonneau and Laarveld, 1999) or GM itself *i.e.* cloned animals (Visscher, *et al.*, 2000).

2.2 Recent developments

The GM plant sector is more developed than GM in animals. There is an increasing number of GM plants that are on, or approaching, the food and feed market. These are herbicide tolerant and insect resistant traits of the first GMO generation (Gilissen and Nap, 2000). GM crops of the first generation that are currently commercialised and used as feed for animals are not only substantially equivalent in composition but are also similar in digestibility and have similar feeding values for livestock (Phipps and Beever, 2000). However, the "first generation GM plants" bring benefit only to the farmers.

There are currently no transgenic livestock food products on the market and it will probably not happen for some years to come. However, there are some interesting developments at the laboratory level. The risks to the environment of GM livestock are considerably less than those potentially associated with GM plants or fish. There is a substantially lower likelihood of escape and dissemination of GM livestock, because of the lack of competition with wild and related animals and bird species. However, in comparison with other GM organisms, there are major public concerns about the acceptability of modifying domesticated animals and about the effects for animal welfare (Sang, 2003).

2.3 Livestock chain view and GM applications in livestock production chains

The chain presents a mechanism with many activities from the level of input, through processing along the chain, to delivery of the final product to the consumer (Sinclair, 2002). The livestock production chain consists of several stages, i.e. animal breeding, growing, slaughtering, processing, retailing and the consumer (Figure 1). At the growing stage animals get medication (vaccinations), feed, which is mostly supplied from outside the farm (EU and Non-EU countries) and supplements to feed (hormones, feed additives, micro-organisms).

GM applications in livestock fall into three main areas: animal production, human nutrition and healthcare (Sang, 2003). This paper focuses on applications relevant to the animal production. According to Figure 1, the applications of transgenic technologies are possible in following stages of the chain, i.e. *animal breeding* (genetic modification of animal itself), *growing* (genetically modified medication, feed and feed supplements, such as feed additives, hormones, micro-organism) and *processing* (using GM bacteria). At this moment

only for these stages of the chain experiments have been done or GM products already exist. GM animals only exist at the laboratory level. However, some GM feed (e.g. soya, corn) and GM feed supplements (e.g. GM enzymes) are already widely used. Table 1 shows the various areas in which GM applications can be beneficial, i.e. applications can be beneficial from an economic point of view and/or in the field of animal welfare, food safety, sensory quality or the environment.

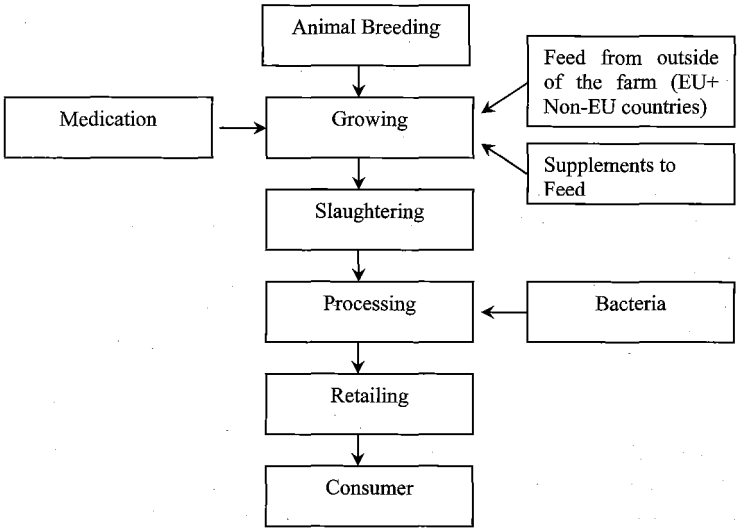

Figure 1. Livestock production chain.

Table 1. GM applications per chain stage and potential benefits.

	Economic/ price/costs	Animal welfare	Sensory quality	Food safety	Environment
Breeding	+	+	+	+	+
Growing:					
Feed	+	+	+	?	+
Feed additives	+	+	+	?	+
Hormones	+	+	+	?	+
Micro-organism	+	+	+	?	+
Vaccines	+	+	n.a.	+	?
Processing:					
Bacteria	?	n.a.	?	?	n.a.

\+ possible application(s)
? no application(s) available (yet)
n.a. not applicable

Animal Breeding

Currently, there are some GM applications in the area of genetic engineering of pigs. New transgenic pigs, developed at laboratory level, may bring different benefits such as leaner pork, improvement of feed efficiency and an increased growth rate. Japanese scientists created pigs with an implanted spinach gene. These pigs produce less fat and, therefore, the meat from these pigs is healthier. Pork from such 'green pigs' contains 20% less saturated fat then normal (BBC News, 2002). Another application, which is also aimed at improving the

fat content, is the incorporation of a growth factor gene (IGF-1). In a study by Pursel, *et al.*, (1996) it was found that the IGF-1 transgene helped reduce carcass fat and boost lean body mass, making hogs worth $6 more at the market than the control pigs without the IGF-1 transgene. Another application includes sows that produce more milk leading to an increased growth of transgenic-reared piglets which results in lower feed costs, less use of antibiotics and less pollution (Noble, *et al.*, 2002). Phosphorous pollution from manure of monogastric animals, including pigs and poultry, is a major environmental issue. Canadian scientists developed genetically modified pigs that produce manure containing up to 75% less phosphorous (so called "Enviropigs") (Golovan, *et al.*, 2001). The use of genetic modification to increase disease resistance may reduce the requirement for treatment with antibiotics and as a consequence also reduce the level of antibiotics in animal products and spread of antibiotic resistance.

Animal Growing

At the growing stage there are many possibilities for GM applications in feed, feed additives, hormones and vaccines. The main sources of feed for animals are crops. Many genetically modified plants have been introduced into the market. Mostly, these crops improve the agronomic characteristics, such as herbicide and pesticide resistance. However, there are some new varieties with improved feeding value through incorporated phytase. This application is not only economically beneficial, but is also beneficial for the welfare of the animal i.e. it helps animals to digest phytase. Moreover, this application allows the reduction of phosphorus, which results in benefits for the environment. Current studies focus on incorporating edible vaccines, antibodies, enzymes and hormones in plants. These applications will not only have economic implications, such as reduced costs and an increased growth rate, but will also affect aspects of animal welfare and the environment. Feed additives such as nutrients, enzymes and immune product supplements have a significant role in enhancing livestock nutrition. With better nutrition, animals digest feed more efficiently and, therefore, become healthier and more productive.

Processing of livestock products

At the processing stage, applications of GM bacteria may help to make the preservation process more effective.

3. A CONCEPTUAL FRAMEWORK FOR TECHNOLOGY ADOPTION

The great number of possible GM applications along the chain as presented in the previous section and the potential numerous benefits that they bring complicates the understanding of the adoption of new technologies. Our conceptual framework is aimed at structuring all such information for further analyses (Figure 2).

The adoption of new technology is not an easy task, especially in food chains, were consumers are generally very strict to changes and evaluate new developments with special attention. Biotechnology is no exception. Previous research on GM mostly concentrated on the adoption of biotechnology by farmers, not taking into account consumers (Chung and Pettigrew, 1998; Abadi Ghadim and Pannell, 1999, Desquilbet, *et al.*, 2002, Nadolnyak and Sheldon, 2002, Qaim and Janvry, 2003). However, the increasing concerns about healthy and safe food, as well as growing environmental and ethical concerns give consumers' opinion an important role in the process of successful adoption. The suggested framework for technology adoption therefore takes the consumer as a starting point. Consumer acceptance of GM products and consumers' willingness to buy highly depend on the perceived risks during consumption, concerns and benefits. Although consumer perceptions are considered central,

also producers in the food chain must adopt a new technology. For them the same issues are relevant, i.e. (perceived) risks, concerns and benefits. Furthermore, producers' decisions depend on regulations.

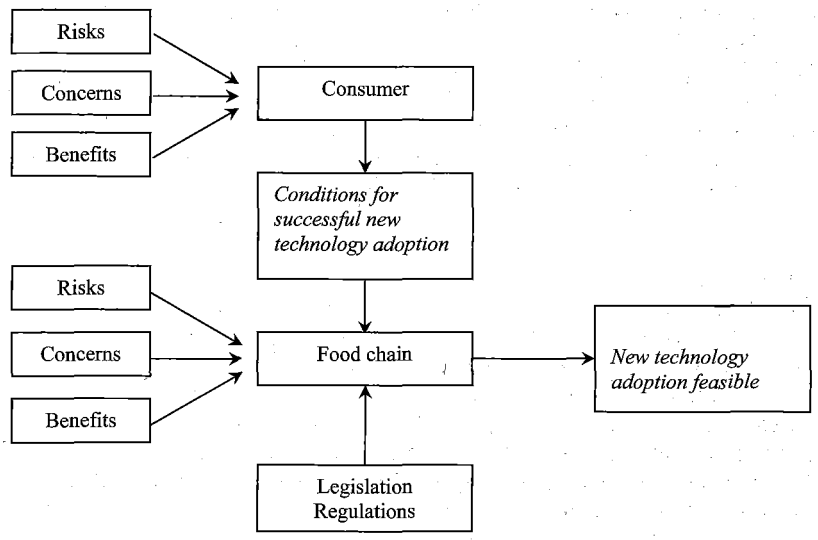

Figure 2. Conceptual framework for new technology adoption in food chains.

Table 2. GM adoption literature for consumers and producers categorised by risks, concerns, and benefits.

	Risks	*Concerns*	*Benefits*
Consumer	*Lehrer, 1999; Siegrist, 2000; Hansen, et al., 2003*	*Frewer, et al., 1996; Gaskell, et al., 2000; Macer and Chen Ng, 2000; Chern and Rickertsen, 2002; Moses, 2002; Spinger, et al., 2002 Verhoog, 2003*	*Frewer, et al., 1996; Gaskell, et al., 2000; Macer and Chen Ng, 2000; Schmidt, 2000; Engel, et al., 2002; Moses, 2002; Bruhn, 2003; Sang, 2003*
Producer	*ACGA, 2001; Fernandez-Cornejo and McBride, 2002*	*ACGA, 2001; Fernandez-Cornejo and McBride, 2002*	*Chung and Pettigrew, 1998; Phipps and Beever, 2000; Engel, et al., 2002; Moses, 2002; Bruhn, 2003*

According to the suggested framework, Table 2 presents the available literature on consumer and producer risks, concerns and benefits. Consumer understanding and acceptance are crucial to the future of food biotechnology (Schmidt, 2000). Attitudes towards genetic modification vary between countries (Cantley, *et al.*, 1999; Gaskell, *et al.*, 2000). American and Canadian consumers seem to be more positive towards the technology (Hoban, 1999) compared to consumers in Europe (Cantley, *et al.*, 1999; Gaskell, *et al.*, 2000).

The main source of risks for consumers with respect to GMO is a health risk (Lehrer, 1999). Among consumers' concerns "unnaturalness" of GM food plays an important role in consumer attitudes towards gene technology (Verhoog, 2003). Also there are substantial

public concerns about the use of GM technology in animals (Gaskell, *et al.*, 2000; Moses, 2002). Consumers have been shown to have more positive attitudes towards the use of genetic engineering for medical applications than for food production purposes (Gaskell, *et al.*, 2000). In general, medical applications are perceived to be more beneficial, less risky and more ethically correct than applications of GM technology to food production (Enriquez, 2001). Frewer, *et al.*, (1998) found that GM micro-organisms and plants were associated with less risk compared to GM animals. That suggests that consumers accept GM technology differently depending on different areas of applications of the GM technology and type of application (Grunert, *et al.*, 2001)

With respect to producers, the potential risks and concerns are mainly defined by consumers' acceptance of the technology (ACGA, 2001; Fernandez-Cornejo and McBride, 2002). Benefits accrue to lower production costs, higher yields and decrease dependence on weather conditions (Chung and Pettigrew, 1998; Phipps and Beever, 2000; Engel, *et al.*, 2002; Moses, 2002).

4. FUTURE OUTLOOK

Results of this study are the basis for further investigations of new technologies in food production, and, specifically, GM in livestock production chains. The literature review is used for organising a consumer survey to deeply analyse consumer perceptions with respect to new technologies in livestock production. The proposed chain approach helps to analyse technology adoption in the full range.

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