TOWARDS GREEN SUPPLY CHAIN MANAGEMENT IN AGRICULTURAL SECTOR: APPROACH TO LOGISTIC DESIGN FOR UTILIZATION OF BANANA-PLANTAIN PSEUDO-STEM FIBER

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2 authors:

Carlos Orrego
National University of Colombia

Johana Rodriguez
Fundación Universitaria Luis Amigó

Green Supply Chains: applications in agroindustries

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EDITORS

Carlos Ariel Cardona Alzate.

William Ariel Sarache Castro.

Universidad Nacional de Colombia Sede Manizales.

Instituto de Biotecnología y Agroindustria.

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Carlos Ariel Cardona Alzate - William Ariel Sarache Castro
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ABSTRACT

One of the megatrends in the study of the supply chain is the need to incorporate "green practices" in its design and management as a demonstration of the environmental commitment of the companies. Such trend, is strongly related to the concept of Green Supply Chain Management (GSCM). GSCM aims to avoid waste of resources during the product life cycle, to ensure not only environmental sustainability but also more efficient production, taking into consideration a balance with the environment as a competitive priority that generates value added for the companies. In this way, the present book shows the results of eight investigations that have studied some issues related to the GSCM concept. The book was deleveloped under a collaborative effort between the Universidad Nacional de Colombia and other institutions such as *Escola Superior de Tecnologia e Gestão, Instituto Politécnico de Portalegre (Portugal), Escuela de Ingenierías Industriales Universidad de Extremadura (Spain) and The University of Leoben (Austria)*.

CONTENTS

PREFACE

One of the megatrends in the study of supply chains is the need to incorporate "green practices" in its design and management as a demonstration of companies environmental commitment. Such trend, which has its origins in the decade of the 90s, was strengthened from other concepts such as environmental management, reverse logistic, corporate social responsibility, life-cycle analysis and closed-loop supply chains, among others, until reach the current concept of Green Supply Chain Management (GSCM).

GSCM aims to avoid waste of resources during the product life cycle, to ensure not only environmental sustainability but also more efficient production, taking into consideration a balance with the environment as a competitive priority that generates value added for the companies. GSCM, as other areas of management, has evolved along the time. Initially it was focused on the implementation of environmental improvements in procurement and production activities (reactive approach). However, later it spread to other activities of the supply chain such as marketing, transportation and customer service.

The GSCM concept addresses the integration of environmental thinking into supply chain, including design, selection of raw materials, manufacturing processes, product delivery as well as product handling after consumption. The green focus, in supply chain management, promotes the integration of four main aspects: green purchasing, green manufacturing/materials management, green distribution/marketing and reverse logistic.

In this context, without the interest to address all issues of the field of study, the book presents results of eight investigations that have studied some issues related to the GSCM concept. The chapter 1, 6 and 7 address the conceptual bases and particular topics related to the green supply chain management, exposing the entire field of study and current trends. The remaining chapters address research results related to waste utilization in different supply chains such as shrimp industry (Chapter 2), banana-plantain (Chapter 3), agroindustrial byproducts for building industry (Chapter 4), biopolymers (Chapter 5) and biofuels (Chapter 8).

The present contribution is the result of a collaborative effort between the Universidad Nacional de Colombia and other participating institutions such as Escola Superior de Tecnologia e Gestão, Instituto Politécnico de Portalegre (Portugal), Escuela de Ingenierías Industriales Universidad de Extremadura (Spain) and The University of Leoben (Austria). The main objective is the dissemination of research outcomer and advances related to green topics in an attempt to contribute to the field of study.

CHAPTER 1

GREEN SUPPLY CHAINS: CONCEPTUAL BASES AND TRENDS

Jhully Martinez Giraldo
William Ariel Sarache Castro

Universidad Nacional de Colombia Sede Manizales

INTRODUCTION

Nowadays it is evident that environmental degradation of the planet is a consequence of industrialization and economic globalization. The air and water pollution, the devastation of entire forests to facilitate agriculture and grass for livestock as well as greenhouse gases and solid waste, are some issues that the human race faces as a result of the environmental impact generated by technology development and market growth around the world. These problems, as was feared in the past, are a reality that affects the life quality of the common citizen at present.

The population growth and the increase of industrial production to meet global consumerism have caused serious concerns requiring the adoption of a sustainable development model that allows the survival of future generations. Different approaches have been undertaken to achieve an appropriate balance between economic growth and environmental sustainability; these include preventive and corrective activities. In this process the legislative role has been indispensable, requiring the management of environmental effects generated by companies and promoting both the use of clean technologies and materials that do not affect the population´s health and food security.

To achieve this goal, several improvements have been carried out in soft and hard technologies. The former include processes intensification and using of renewable energies; in the latter, the implementation of ISO 14000 standard and TQM approaches (Total Quality Environmental Management) have had a significant progress. However, one of the most important and comprehensive environmental advances, happened in recent years, is the development of the green supply chain management concept (GSCM). The GSCM proposes the integration of environmental thinking throughout the supply chain as a competitive priority incorporated to competitive strategy. The aim of GSCM is to reduce materials consumption, energy and other resources in order to decrease negative effects on the environment, and at the same time, achieving the best outcomes in productivity, profitability and customer service.

In this sense, the present chapter aims to show an approach to the GSCM concept. For this purpose, and initially, a review of the most relevant international environmental legislation is presented. Then, an approximation to the state of the art related to green practices in supply, manufacturing and distribution operations is developed. Finally, some trends and challenges that have emerged in recent years about this topic are analyzed.

ENVIRONMENTAL CONCERNS AND SOME INTERNATIONAL REGULATIONS

The environmental concerns encompass several problems that affect the quality of life on the planet. This includes issues such as ecosystems pollution, availability and quality of water and air, uncontrolled growth of cities, incorrect use of land and inadequate disposal of solid waste, as well as their social, political and economic implications. One of the greatest concerns for governments and society is pollution; this happens when a strange agent, temporarily or permanently, unbalances the environment causing adverse effects on human, fauna and flora (RAE, 2012). Pollution may be generated through air, soil and water or by effect of electromagnetic radiation, among others.

The pollution of water, soil and air are closely linked. For example, the shedding of pesticides into the soil contaminates water bodies due to entrainment and lixiviation processes; also, if some volatile substances are present, it will go directly into the atmosphere. Moreover, due to population growth and consumption needs, agricultural systems and manufacturing are encouraged to increase their market share, generating greater natural resources consumption and increasing emissions to the environment. In some places of the world, the industrial growth is not depleting only the natural resources, but also it is moving into a dangerous competition to get water and other vital resources affecting communities quality of life.

In this scenario, another important issue is air pollution. According to IDEAM (2008), the smoke and ashes produced by fossil fuels consumption and the growing use of cars, have become an enormous collector of waste in the air. As a result of human activity, large amounts of waste such as sulfur oxides, carbon monoxide, nitrogen oxides, ozone, lead and particulate materials are sent to the atmosphere every day. This situation has been identified as the main source of acid rain and global warming, affecting seriously not only human health but also the economy (OMS, 2011). Far from an early solution, the problem has been growing for several decades due to population increase and its consequent urban and industrial growth. In recent decades, several international agreements have been signed to avoid the irreversible effects on health and economy.

Pollution is caused not only by industry but also by commercial activities and consumerism, which is overflowing some societies. However, the most dangerous substances mainly come from toxic waste and reactive, flammable and combustible materials produced in mining, oil, chemical and leather industries (IDEAM, 2011). These poured wastes into water bodies are increasing heavy metals concentrations and pathogenic microorganisms affecting the land morphology. Since pollution is global, legislation plays a vital role in environmental control.

In recent years the concern of governments and nongovernmental organizations has focused on the design of strategies and regulatory frameworks to promote a balance between development and environment. Because the pollution problems are a matter of strategic importance to human survival and economic growth, today environmental problems make up the agenda not only of governments but also of companies. With the growing of environmental problems, the increase of international and local regulations requiring the adoption of clean technologies and strategies to reduce the natural resources consumption has been significant. These regulations make up a legal framework that should be taken into consideration not only in the strategic planning process of companies but also in the supply chain configuration.

Society, environmental legislation and trends in corporate social responsibility, are recognized as the main actors who press organizational change towards a business model less harmful to the environment, people and the economy. To meet the current needs in environmental matters, the existing regulatory framework in most countries, defines the guidelines related to the efficient use of raw materials, energy and water, as well as regulations for facilities location and operation and technical management of emissions such as solid wastes, discharge of pollutant materials into water ecosystems, air pollution, noise and other actions that affect society and environment (UPME, 2010).

Moreover, international regulations establish new requirements and commitments for governments and companies. This situation becomes a strategic issue for companies that are planning growth in the global market. Some significant examples about regulatory changes have occurred in the recovery of carpet components (Biehl et al. 2007), the German packaging law that imposes a minimum recycling percentage (Fleischmann, 1997) and Dutch law to recycle used vehicles (Cairncross, 1992). Table 1.1 presents some of the best-known regulations in the international context addressing different issues that shape the global agenda of environmental protection, such as protection of the ozone layer, industrial discharges, global warming and management of toxic substances, among others. This scenario raises a new policy framework for companies, not only to avoid economic sanctions but also to access international markets.

Table 1.1. Some regulations and international agreements

Year of adoption	Agreement	Target
1992	Rio Declaration on Environment and Development	Creating new levels of cooperation among States, key sectors of society and people to protect the integrity of the global environmental and development.
1987	Montreal Protocol on Substances that Deplete the Ozone Layer	Protecting the ozone layer by phasing out the production of numerous substances believed to be responsible for ozone depletion.

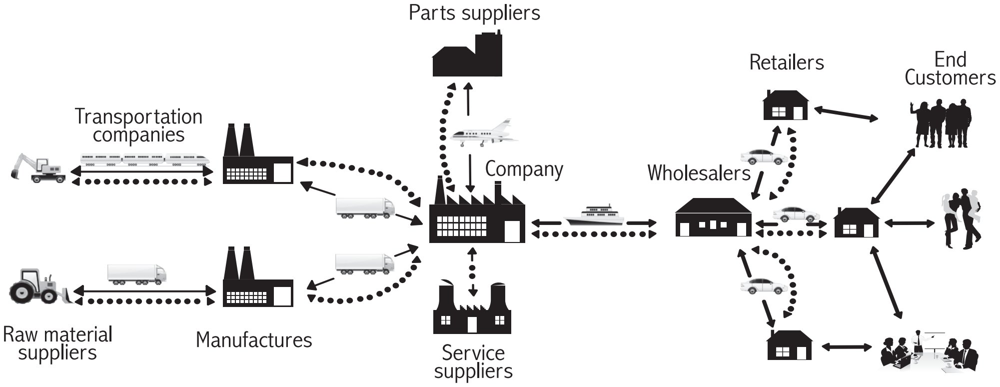
1989	Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal,	Reducing the movements of hazardous waste between nations, and specifically to prevent transfer of hazardous waste from developed to less developed countries
1992	Convention on Biological Diversity	Conservation of biological diversity, sustainable use of its components and fair and equitable sharing of benefits arising from genetic resources.
1992	The United Nations Framework Convention on Climate Change	To stabilize concentrations of greenhouse gases in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system; to allow ecosystems to adapt naturally to climate change; to protect food production and support the growth of sustainable economic development.
1998	Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade.	Promote shared responsibility and cooperative efforts in the international trade of certain hazardous chemicals in order to protect human health and the environment.
2001	Stockholm Convention on Persistent Organic Pollutants	To eliminate or restrict the production and use of persistent organic pollutants.
2005	Kyoto Protocol	To limit or reduce emissions of four greenhouse gases (GHG) (carbon dioxide, methane, nitrous oxide, sulphur hexafluoride) and two groups of gases (hydrofluorocarbons and perfluorocarbons). All countries collectively agreed to reduce their greenhouse gas emissions by 5.2% on average for the period 2008-2012, relative to their annual emissions in a base year, usually 1990.

Source: Compiled from the official home page of MAVDT (2012)

THE CONCEPT OF GREEN SUPPLY CHAIN MANAGEMENT

Waters (2007) defines supply chain (SC) as a set of organizations through of which materials and information are moved from the raw material suppliers until end customers. Christopher (2005) defines SC as a network of independent and interconnected companies working cooperatively to manage and improve the materials flow and information from suppliers to end consumers. As shown in Figure 1.1, SC involves customers, distributors (wholesalers and retailers), manufacturers, raw materials suppliers, carriers and suppliers of several services, among others.

Figure 1.1. A simplified representation of the supply chain



Source: Sarache Castro (2013)

The supply chain is a complex organizational system (Chandra and Grabis, 2007). All companies are connected through the materials flow, information and money. These flows occur in two directions and can be managed by each company directly or through an intermediary. The coordination of plans and activities sets the business relationships between supply chain members, according to how they share responsibility for achieving a common goal.

Given its characteristic as an open system, supply chain affects its environment and also it is affected too, not only for the commercial, political, technological and economic context, but also by environmental issues. For example, weather-related issues are essential to some food supply chains. Likewise, topography may become a decisive factor for the survival of some supply chain companies by affecting diverse operations such as transportation, manufacturing and marketing among others; moreover, manufacturing facilities and distribution centers located in mountains are often affected by landslides and floods during the rainy season, which in turn, affect transportation infrastructure. For its part, supply chains affect the environment and, in many cases, are the largest generators of waste and emissions that affect the quality of soil, water and air.

In the business management context, the earliest green concept was limited to a reactive approach focused on environmental improvements in manufacturing operations and purchasing. Subsequently, it was extended to other supply chain stages beyond the production process, such as transportation and waste disposal. (Godfrey, 1998). One of the most important precedents in the green approach is the reverse logistic concept (RL); RL is responsible for the management of return flows such as rejected products, products for recycling or remanufacturing, reprocessing materials, used products and waste disposal. Due to growing of environmental pressures and the incorporation of sustainability as a strategic factor in companies, the adoption of green practices in supply chain management, has given way to a more advanced and comprehensive concept known as Green Supply Chain Management (GSCM).

Hu and Shu (2010) argue that there is no consensus on the definition of GSCM and therefore this can be redefined according to the aims of the organization and the purpose of its implementation. Srivastava (2007) argues that GSCM addresses the integration of environmental thinking in the supply chain, including design, supplier selection, manufacturing processes, distribution and product handling after use. Meanwhile Wu et al. (2011) state that GSCM involves the integration of social, environmental and economic development within the SC where information sharing can benefit the employees, shareholders, partners and community. Sarkis (2012) defines the GSCM as incorporating environmental considerations into all of supply chain activities, such as design, purchasing, procurement, manufacturing and distribution.

Table 1.2 shows some contributions related to the evolution of GSCM concept over the last 15 years.

Table 1.2. Some contributions related to the evolution of the GSCM concept.

Year	Author	Concept of GSCM
1998	Green et al. (1998:94)	*"Green supply refers to the way in which innovations in supply chain management and industrial purchasing may be considered in the context of the environment".*
1998	Narasimhan and Carter. (1998) quoted by Toke et al (2010:1).	*"Environmental supply chain management consists of the purchasing function's involvement in activities that include reduction, recycling, reuse and the substitution of materials".*
2001	Min and Galle (2001:1222)	*"Proactive environmental programs include making "green" (environmentally-sound) products, developing reusable packages, conserving energy, reducing waste, recycling, creating an environmentally sensitive corporate culture, and integrating total quality environmental management into the firm's planning processes".*
2006	Vachon and Klassen (2006:796)	*"A more externally oriented approach involving the application of environmental management principles to the supply chain has emerged as a new way to address the sustainability challenge".*
2007	Srivastava (2007:55)	*"Integrating environmental thinking into a supply chain management, including product design, material resourcing and selection, manufacturing processes, delivery of the final product to the consumer as well as end-of-life management of the product after its useful life".*

2008	Seuring, et al. (2008:1700)	*“We define sustainable supply chain management as the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements”.*
2010	Kogg (2010:158)	*“Supply chain management as a universal solution both as a means to maximise efficiency and effectiveness and as a universal model for achieving environmental or social objectives in the supply chain”.*
2011	Wu et al. (2011:384)	*“GSCM is as an effective management tool and philosophy for proactive and leading”.*
2011	Kuik et al. (2011:985)	*“Supply chain management is defined as the integration of the social, economic and environmental aspects within a global supply chain that provide sustainable product, excellent services and accurate information sharing may be beneficial to all employees, shareholders, business partners and the wider community at large”.*
2012	Sarkis (2012:202)	*“Supply chain management integrative aspects which include marketing customer relationship and distribution management, logistics and materials management, purchasing and procurement, as well as standard production and operations management areas, provided an important existing foundation for expanding the business management scope, with environmental management a natural research direction”.*

Source: Own elaboration based on the quoted authors

THEORIES AND MANAGEMENT APPROACHES THAT SUPPORT GSCM CONCEPT

In the study of GSCM two perspectives are clearly identified: the first one, organizational theories and their impact on the incorporation of green practices in organizations; the second one, environmental management approaches and their conceptual and technical contributions in the adoption of green practices.

Perspective of organizational theories

From the perspective of organizational theory, nine approaches have been identified: complexity, ecological modernization, information, institutional, resource based, resource dependence, social network, stakeholder and transaction cost-economics.

The complexity theory addresses the external operations of GSCM such as the cooperation with suppliers, customer relationships, handling of returned products and environmental effects, among others. Likewise, it offers guidelines to solving difficulties arising in the integration efforts and environment adaptation of the company based on its size, economic activity and supply chain features (Vachon and Klassen, 2006). The ecological modernization theory is related to external agents that promote technological innovation and policies against pollution; also this theory encourages companies to make a continuous environmental assessment in order to improve their environmental performance and in turn their competitive position through implementation of green practices Jänicke (2008).

The information theory addresses information sharing between companies, customers and suppliers to achieve more effectively common benefits in environmental issues and joint certifications of their environmental management systems (Kuik et al., 2011). The institutional theory is based on normative, coercive and mimetic models as a way to pressure changes in the organization’s policies about environmental issues. The resource-based theory promotes the company competitiveness using valuable resources, unusual, unique and non-substitutable (Ball and Craig, 2010).

The resource dependence theory promotes collaboration between business organizations in order to get mutual benefits (Carter and Rogers, 2008). For its part, the theory of social networks suggests that good results depend on the strength of the working relationship between companies or its employees; some applications of these two theories in the GSCM field are common in development of supplier’s relationships and eco-design. The stakeholder theory addresses the externalities of the company that affect internal and external customers, increasing pressure to reduce negative impacts on the environment (De Brito et al., 2008; Delmas and Montiel, 2009). Finally, the transaction cost-economics theory analyzes the effort and cost required to perform an activity; some analysis performed by using mathematical programming and optimization models in environmental studies along the supply chain are examples from this perspective (Sarkis et al., 2011).

Perspective of environmental management approaches

From environmental management perspective, four approaches are the most relevant: Environmental Management Systems, Total Quality Environmental Management, Industrial Ecology and Clean Technology.

The aim of Environmental Management Systems (EMS) is the implementation of specialized processes and procedures to improve the environmental performance of companies. For this purpose EMS must be engaged in the policies, objectives and strategic goals of the company in order to ensure regulatory compliance and waste reduction (Melnyk et al., 2003). Arimura et al. (2011), in an analysis of the relationship between EMS and GSCM, presented evidence of the positive effect of EMS, not only on the structuring and development of green supply chains, but also on costs reduction of its implementation.

The Total Quality Environmental Management (TQEM) is a systemic approach associated with design, manufacturing and disposal of products and materials. The main objective of TQEM is to reduce the waste generated by companies, through the optimization of technical and human resources. This approach is based on the principles of Total Quality Management (TQM) and continuous improvement (Raluy, 2009). Curkovic and Sroufe (2006) pointed out that TEQM enables companies to improve their efficiency in waste management and decision-making related to environmental protection. Meanwhile Haden et al. (2007) argue that TQEM is one of the pillars of Green Supply Chains, which addressed the integration of environmental costs in business processes and introduced the development of environmental strategies in the corporate strategy to create a distinctive advantage.

The Industrial Ecology aims to boost the development of symbiotic links between industrial processes. This approach, based on the concept of Life Cycle Analysis, establish that flows of matter and energy occur within a closed loop that integrates several companies, where wastes a certain company are the raw materials of thenext (Raluy, 2009). The concepts of industrial ecology and reverse logistics are clearly linked because these seek to create value added from the use of waste generated throughout the supply chain in order to create new products within the same chain or in other related chains (Allenby, 2000; Cervantes, 2007).

Finally, Clean Technology (CT) is a concept associated with the reduction of resource consumption and waste generation. CT is strongly linked to Product Lifecycle concept and proactive approach (Raluy, 2009). This is based on the idea of improving processes to increase efficiency and save energy and non-renewable resources, and by this means, obtain economic benefits and increase competitive advantage (Eder and Sotoudeh, 2000). Clift and Wright (2000) conducted a study in which they analyzed the environmental impacts of a supply chain and noted the need to adopt clean technologies to achieve significant improvements in its processes. The relationship between Green Supply Chains and clean technologies was studied by Linton et al. (2007); they concluded that implementation of these technologies can improve the environmental sustainability of production chains, which is consistent with objectives of GSCM approach.

PROCESSES AND ACTIVITIES OF GSCM

The processes and activities of GSCM is one of the study fields that shows greater contributions in the state of art; however, there are several approaches that depend on the point of view of each investigator. Srivastava (2007) divides GSCM in green design and green operations; the latter embraces the concepts of green manufacturing and remanufacturing, reverse logistics, green distribution and waste management. Hervani et al. (2005) propose a structure for GSCM by dividing it in six topics: green purchasing, green manufacturing, material management, green distribution, green marketing and reverse logistic. In turn Al-Odeh and Smallwood (2012) proposes four processes: design and sustainable packaging, sustainable production, sustainable transportation and sustainable purchasing and marketing. Meanwhile Toke et al. (2010), in a structure based on material flows, suggests three main processes: 1) procurement, materials and inbound logistics; 2) production, distribution and outbound logistics; and 3) reverse logistics. Based on the contributions of several authors, it is possible to set the structure of GSM and its activities in 5 main processes: green design, green purchasing, green manufacturing, green distribution/ marketing and reverse logistic. Table 1.3 presents a summary of each process.

Table 1.3. Processes and activities of GSCM

PROCESS	ACTIVITIES
Green Design	• Selection of nonpolluting and recyclable materials. • Life Cycle Analysis. • Elimination of polluting operations. • Packaging design and recyclable packaging. • Design for remanufacturing and disassembly.
Green Purchasing	• Providing design specification to suppliers that include environmental requirements for purchased items. • Cooperation with suppliers for environmental objectives. • Environmental audit for suppliers. • Suppliers' ISO14000 certification. • Second-tier supplier environmentally friendly practice evaluation.
Green Manufacturing	• Investment recovery (sale) of excess inventories/materials. • Sale of scrap and used materials. • Sale of excess capital equipment. • Design of products for reduced consumption of material/energy. • Design of products for reuse, recycle, recovery of material. • Design of products to avoid or reduce use of hazardous of products and/or their manufacturing process. • Total quality environmental management Environmental compliance and auditing programs • ISO 14001 certification.
Green Distribution/Marketing	• Cooperation with customer for eco-design. • Cooperation with customers for cleaner production. • Cooperation with customers for green packaging. • Optimize the transportation system. • Reduce the finished goods inventory in warehouses and stores.
Reverse Logistic	• Reuse. • Repairing and restoration. • Disassembly (remanufacturing and cannibalization). • Recycling.

Source: Own elaboration based on contributions of Zhu et al. (2005); Zhu et al. (2008); Murayama (2005); Alshamrani et al. (2007).

Green Design takes into account environmental safety and population health (Srivastava, 2007). Its activities are focused on replacing polluting materials by greener materials as well as on making structural changes in products in order to produce less waste and facilitate its inclusion in the so-called closed loop supply chain (Keeping and Shiers, 1996). Green design includes raw materials selection, packaging design and redesign. The Life Cycle Analysis (LCA) and environmentally conscious design (ECD) are two of the main activities of Green Design (Shi et al., 2012). LCA consists of assessing the environmental impact of a product from its stage of raw material until its final distribution on the market and the subsequent disposal (Björklund, 2012). In turn, EC is a methodology that evaluates product design decisions and their compatibility with environment (Ilgin and Gupta, 2010; Madu et al., 2010).

Green purchasing are supported on environmentally conscious management practices, reducing environmental impact and promoting recycling, waste recovery and materials reuse by suppliers (Min and Galle, 2001). These include several activities such as supplier selection based on environmental criteria, cooperation with suppliers for environmental objectives, environmental audit of suppliers, and suppliers' ISO14000 certification, among others. Chen (2005) studied the advantages of implementing ISO 14000 standards in purchases and emphasizedthe importance of engaging suppliers in certification process in order to work together on environmental protection projects. According to Sarkis (2001), the development of capacities in environmental protection has become a key criterion in supplier's selection process as important as cost, quality and service.

Green Manufacturing is focused on a set of activities in the production stage to guarantee a closed loop by adopting clean technologies and environmental strategies. Some activities are the investment recovery (sale) of excess inventories/materials, sale of scrap and used materials, sale of excess capital equipment, design for reduce energy and material consumption, total quality environmental management and environmental compliance and auditing programs (Ferguson and Toktay, 2006; Wong et al., 2012). Srivastava (2007) divides this stage of supply chain in two parts: green manufacturing and green remanufacturing. The first is aimed to reduction of energy consumption, overproduction and resources in order to decrease the consumption of virgin materials through improvement of production scheduling, sales forecasting and inventory management. The second is focused on recycling integration and manufacturing operations; this activity is oriented to material recovery, reuse, repair, cannibalization and disassembly (Xiaoyan, 2012).

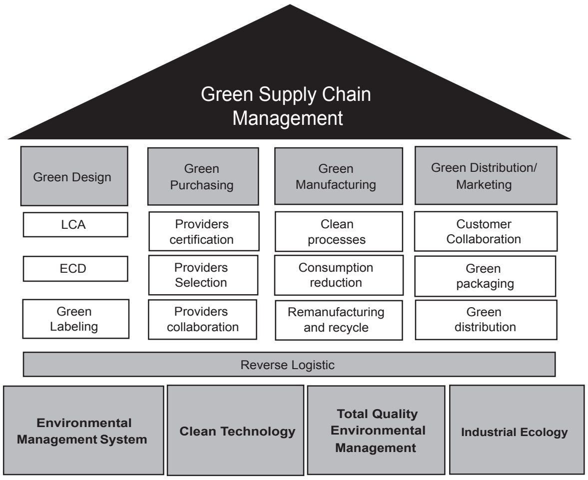
Green Marketing focuses on marketing of environmentally safe products as well as on developing of collaborative strategies with distribution channels to reduce environmental effects (Grant, 2008). This includes activities related to cooperation with customer for eco-design, cleaner production and green packaging. Peattie and Crane (2005) suggest that it is necessary to integrate green marketing with other stages of the supply chain to ensure that it is not only focused on customer requirements, but it also meets the environmental regulations generating long-term benefits to the company. From this perspective, the relationship between green marketing with other activities such as green design, reverse logistics and green manufacturing is well identified in the state of art.

Green distribution addresses the environmental impact of post-manufacturing activities, through all stages of commercialization process until the product reaches the final consumer. Green distribution is made up of various activities such as waste management and friendly transportation systems. Waste management is responsible for reduction at source, pollution prevention and disposal (Srivastava, 2007; Nunes and Bennet, 2010). Friendly transportation systems promote the use of non-fossil fuels to reduce air pollution and other negative effects such as noise pollution; it also support the implementation of programs for proper disposal of burned oil, tires and other components. Likewise, it promotes the optimization of transportation systems to reduce vehicle traffic and improve their capacity utilization.

Reverse Logistics (RL) is related to recovery process and creation of value added by using products and materials return (Jack et al., 2010; Pokharel and Mutha, 2009). The Reverse Logistics Executive Council, (2013) defines LR as "the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal". For its part, The Supply Chain Council (2008) identifies three types of return flows in LR: return of defective products, return for maintenance/repair and return of products out of season. RL and GSCM are two closely related concepts by which environmental sustainability has made significant progress in recent years (Lambert et al., 2011).

A conceptual model that summarizes the structure and activities of GSCM is shown in Figure 1.2. In it, EMS approaches, Clean Technology, Industrial Ecology and TQEM represent the foundations that provide the conceptual basis for supporting the management model. For its part, activities making up green design, green purchasing, green manufacturing, green distribution/marketing and reverse logistic, are shown as the pillars holding up an organizational management approach that promotes the adoption of green practices throughout the supply chain involving suppliers, manufacturers, distributors and customers. The model in Figure 1.2, proposes a comprehensive approach that, beyond the adoption of green practices, promotes the integration of supply chain, collaboration among its members and environmental sustainability of its activities.

Figure 1.2. GSCM conceptual model



Fuente: Own elaboration based on contributions of Srivastava (2007), Kainuma and Tawara (2006) and Al-Odeh & Smallwood (2012).

Fuente: Own elaboration basedon contributions ofSrivastava (2007), Kainuma and Tawara (2006) and Al-Odeh & Smallwood (2012).

INFLUENCING FACTORS AND BARRIERS IN GSCM DEVELOPMENT

There are several actors pushing companies to adopt green practices. Ai et al. (1996) identified six main pressure agents: government, partners, stakeholders, employees, society and consumers. Khiewnavawonga and Scmidt (2008) coincide with Boks and Stevels (2007) identifying three main groups: scientific green, government green, and customer green. Scientific green addresses the life cycle analysis; government green includes geographic and population factors and green customers gather customer's perceptions about how companies affect their safety and health as a consequence of natural resources deterioration.

The contributions of Zhu et al. (2010) classify pressure agents in internal and external stakeholders; these authors also identified the type of pressure according to three sources: normative, coercive and mimetic. Internal and external groups that have personal interest in the organization often carry out regulatory pressures. The coercive pressures come from both government agencies and international regulations related to the particular business operations of companies. Finally, mimetic pressures occur when a company imitates management practices of successful competitors; for example supporting recycling campaigns or by implementing reverse logistics activities to collect polluting substances.

According to Holt and Ghobadian (2009) external pressure agents come from regulations, society, customers and competitors. In turn, internal pressures come from employees, managers committed with environmental protection and risk management policies of the organization. Other factors that encourage adoption of green practices are costs and risks reduction, particular customer requirements, changes in organizational strategy and competitive pressures among others. (Hu and Hsu, 2008; Diabat and Govindan, 2010).

However, despite the increasing pressures for adoption of green practices, there are several barriers that restrict the implementation of new initiatives aimed to improve environmental sustainability of the organization. According to Giunipero et al. (2012), the lack of sustainability standards, erroneous application of objectives, lack of consensus on green concepts and sustainability costs are the main barriers to successful implementation of green approaches. In the same way, Muduli et al. (2012) indicate that insufficient pressure from society, poor legislation, lack of consensus on GSCM concept, financial constraints and unclear methodologies, are the main barriers.

As was addressed in this chapter, organizations are under pressure to adopt environmental policies in their supply chain. Several researchers have positioned environmental requirements at the same level of other competitive priorities such as cost, quality and service. Although there are various perspectives about GSCM concept, many researchers advocate the adoption of green practices within companies as a way to gain competitive advantage and improve the company's environmental responsibility (Srivastrava, 2007; Cheng, 2011, Barari, 2012; Diabat and Govindan, 2010). The challenge is great since the adoption of green practices involves social, economic, technological and regulatory issues, as well as a process of decision-making influenced by various internal and external stakeholders.

SOME RESEARCH TRENDS IN GSCM

As is shown in Table 1.2, the GSCM concept is the result of an evolutionary process through which became an organizational management practice, not only from a theoretical point of view but also from a practical perspective. The evolution of this concept is yet in progress and therefore is exposed as a dynamic and prolific study field that proposes new research lines. Studying trends about green concept and the best way to apply it in specific companies are a clear target for further advances in search of better solutions to the environmental problems under a proper balance between company objectives and pressures from consumers, government and society.

The incorporation of environmental factors within the competitive priorities of organizations is another prominent research trend in the state of the art (Zhu et al. 2008; Olugu et al. 2011). Zhu, et al. (2007) suggest that future research should be conducted toward understanding the weaknesses implementation of GSCM activities in manufacturing companies; they also state that is important to identify the success factors that allow its appropriate development from a strategic perspective. From the innovation point of view, Zhu et al. (2012) proposed new researches to exploring innovative environmental management practices in different industries according to their size, ownership source (public or private) and economic sector that they belong. Furthermore, Sheu and Talley (2011) classified GSCM research perspectives in five main topics: strategic planning and operational models, resource allocation strategies, multilateral relationship management, promotional incentives for sustainable green supply chains and solution of practical cases.

In a research undertaken by Liu et al. (2012), aimed to integrate green marketing with sustainable supply chains, they conclude that it is necessary to investigate the flexibility of sustainable supply chains taking into account the requirements of customers and their attitude toward adoption of green practices. Other green research trends have addressed topics such as product design and packaging, the effect of context as a success factor in GSCM implementation and cooperation between suppliers and customers to adopting green practices (Chan, et al., 2012). In turn Sharma and Iyer (2012) studied the trends in green marketing in a context of limited resources, strong competence and customers with low buying capacity; they propose researches aimed to product development with limited resources as well as to design of green marketing strategies and products in traditional markets.

Related to green purchasing field, research is directed towards the study of cooperation strategies between companies and suppliers. For example, Bay and Sarkis (2010) propose new investigations about green suppliers development to ensure their integration with environmental objectives and organization requirements. Eltayeb et al. (2010) propose new research lines aimed to study pressure factors and agents involved in adoption of green practices, the suppliers reactions to such pressures as well as the proper activities required to develop green suppliers.

In regard to green manufacturing, various research lines such as production planning and control of recycled products, substitution of pollutants raw materials, modular products design to facilitate disassembly processes and reverse supply chains design are some of the most relevant issues (Lombardi et al., 2010; Korchi and Millet, 2011; Shi et al., 2012). Other issues related to process intensification to reduce energy consumption, electronic data interchange (EDI) to support reverse logistic activities, fuzzy logic and neural networks applications for suppliers selection and production scheduling for disassembly processes, among others, are also significant in the scientific community. (Cheng et al, 2012; Hsu et al, 2011; Kuo et al, 2010).

Finally, social and economic effects generated by adoption of green practices are another important investigation trend. The perception of employees, stakeholders, customers, competitors and society about how companies manage their processes, products and waste is a growing research topic and a permanent concern of managers, given its impact on corporate image, profitability and long term survival.

CONCLUSIONS

Given the growth of corporate social responsibility and the increase of environmental regulations around the world, today is not possible to adopt an organizational strategy that does not take into account the effects of their activities and decisions on the environmental balance. Aspects related to global warming, biodiversity, ozone layer, water and air, among others, are concerns from various organizations which pressures have resulted in international agreements that impose restrictions affecting operations and business decisions. Since The Rio Declaration on Environment and Development in 1992, more pressures have been applied on companies to encourage them to consume less resources and increase their recycling efforts and reuse.

As a consequence, incorporating green practices has become a target that gains greater importance in corporate strategic planning. In some cases, environmental issues have been assumed as a new competitive priority at the same level of importance of cost, quality and service. This new strategic approach has allowed the incorporation of green activities in supply operations, manufacturing and distribution to build a new management approach in supply chains known as GSCM. Focus on green supply chain management is based on two types of approaches: environmental management and organizational theories.

Although there is no single accepted definition, GSCM concept seeks to integrate green practices along the supply chain to reduce the natural resources consumption and in turn, reducing waste emissions and polluting materials. Furthermore, GSCM concept raises the idea that it is possible to get economic benefits and gain competitive advantage through two strategies: 1) reducing cost of raw materials, water, energy and other scarce resources; and 2) increasing efforts in recycling and materials reuse. Other benefits are related to improvement of corporate image with society, customers and other pressure agents. From a conceptual viewpoint, GSCM consists of five key processes: green design, green purchasing, green manufacturing, green distribution/marketing and reverse logistic.

Finally, since the concept GSCM is still under construction, several research trends are proposed from the state of the art. Issues related to development of green suppliers, material substitution, ecological design of packaging, consumption reduction of energy and water, design of environmentally friendly transportation systems, development of manufacturing technologies, communication to support green strategies and improving management approaches such as green purchasing, green manufacturing and green marketing, are topics of interest in the scientific community.

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CHAPTER 2

GREEN LOGISTICS IN CHITIN/CHITOSAN INDUSTRY

Carlos E. Orrego
Natalia Salgado

Universidad Nacional de Colombia Sede Manizales

INTRODUCTION

In recent years the shrimp industry has had an important growing, mainly by aquaculture, evidenced by the increasing trade (imports and exports) in the world. The production of shrimp by farming corresponds to 52 to 60 percent of the total shrimp production; the remaining percentage corresponds to the shrimp fishery. Since shrimp consumption can be considered as a luxury, some authors have suggested to link the percapita consume of a country with the commercial movements of the shrimp, if the higher the consumption, can be inferred that the economy of a country is on the rise (Atkearney, 2010).

Natural resource transformation processes could imply losses of flora and fauna and other kinds of environmental effects such as greenhouse gas emissions. In the shrimp chain analysis, it can be considered some impacts as the destruction of mangrove forests, pollution of water bodies, salinization of freshwater, high power consumption by fossil fuels, air emissions and final solid waste disposal. For this reason it is very important to evaluate this activities with a focus on green logistics, a new concept which is defined as a process that involves planning, operating transportation, store, load/unload, and package by way of advanced technology and environmental theory, to cut down environmental impacts and reduce resource consumption (Ting and Yongzhang, 2011). This emphasis of adopting green measures in the industry can even also decrease production costs and get more intangible benefits such as image and reputation enhancement.

Only 65% of the entire shrimp is used for human consumption, the rest are the exoskeleton and cephalothorax being these residues the most used raw material for chitin/chitosan production (Núñez-Gastélum, Sánchez-Machado et al., 2011). On the other hand chitin is the principal biopolymer in nature after cellulose. It is estimated that approximately 10 billion tons of chitin can be biosynthesized each year, from shrimp wastes, crab shell, fungi wastes, and others (Yao, Li et al., 2011) .The most important derivative of chitin is chitosan, obtained by its partial deacetylation in the solid state under alkaline conditions or by enzymatic hydrolysis (Jayakumar, Menon et al., 2010). A market study made in 2010 reported that United States and Japan represents the largest markets worldwide for chitin and chitosan, with a participation of 30 and 20 percent respectively. For these countries most applications of these biopolymers are currently for biomedical use like wound dressing materials and artificial sutures. Other direct uses for chitin and chitosan include paper production, textile finishes, cements, heavy metal chelating agents, photographic products and waste removal. Among derivatives, glucosamine represents the largest segment globally with a representatively of 60 percentage in the market (Global Industry Analysts, 2010).

The extraction and transformation processes for chitin/chitosan manufacture generate environmental, economic and social impacts that are describing throughout this chapter. There are also suggested some strategies associated with green logistics that could reduce the carbon footprint, pollution and excessive water consumption by the production process, to achieve a profitable and friendly environment enhancement of the transformation operations and their supply and distribution chains.

THE SHRIMP INDUSTRY AND ITS SUPPLY CHAIN

Among international seafood trade shrimp is the most important commodity. The shrimp industry has grown for centuries in many parts of the world and today has grown exponentially over the recent years. The shrimp production in Asia and South America has grown between the years 1970 and 1988, from 50,000 tons to 600,000 tons in 1988. (Gillett 2008). Between 1990 and 2005, the highest peak of production was about 3.5 million tons, which was largely driven by shrimp aquaculture that has grown at about 23% over the period and has helped to provide this product to the world market, as the shrimp production by fishing in marine resources decreased because of overexploitation. In 2005, shrimp aquaculture accounted for 52% of global production (Campos, Llinas et al., 2008).

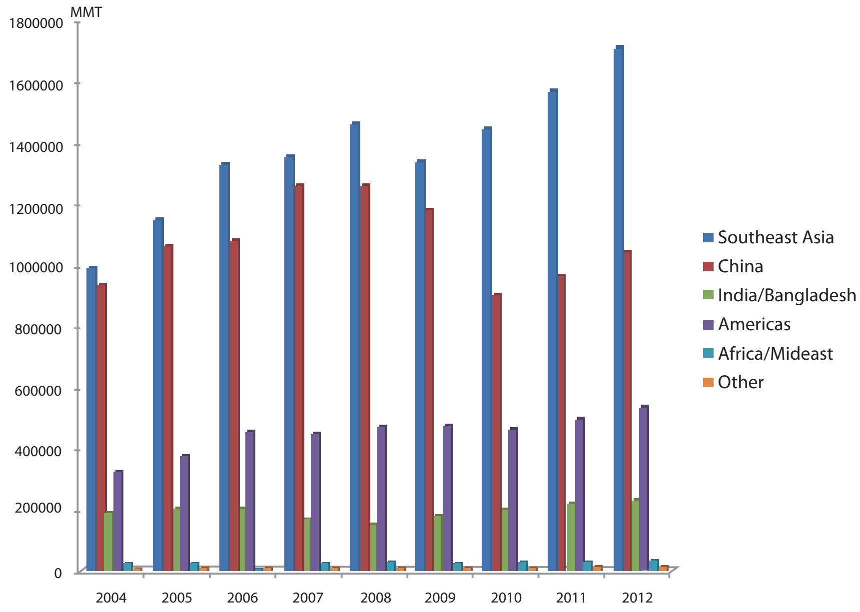
Despite the large number of shrimp species, only a small percentage is commercialized. Among these species are:

- Whiteleg shrimp. The most farmed species of shrimp.
- Giant tiger prawn.
- Akiami paste shrimp. The most intensively fished species.
- Southern rough shrimp. Found only in waters less than 60 m deep.
- Fleshy prawn.
- Banana prawn.

The largest producers are found in Asian continent. China, Thailand, Vietnam and Indonesia accounting for 86% (three million tons) of the shrimp farmed in 2009. In Central and South America, Ecuador, Mexico and Brazil contributed approximately with 13.7 % of the production, being Brazil (1.9%) the tenth country in the global ranking (Fontinele and deAraújo, 2012). Figure 2.1 shows the shrimp aquaculture production by region. It can be observed that the Southeast Asia is the major producer, followed by China, and America.

The different products that can be obtained from shrimp have been quickly incremented. Currently, shrimp may enter the market according to differential quality standards, fast delivery, stable supply, new marketing conditions, compliance with environmental regulations, social responsibility, etc. The completion of one or several of these conditions allowing the shrimp to maintain or capture new market niches (Wurmann, Madrid et al., 2004).

Figure 2.1 Shrimp aquaculture production by major producing regions 2004-2012



Source: (Jory, 2011)

GLOBAL MARKET SURVEY

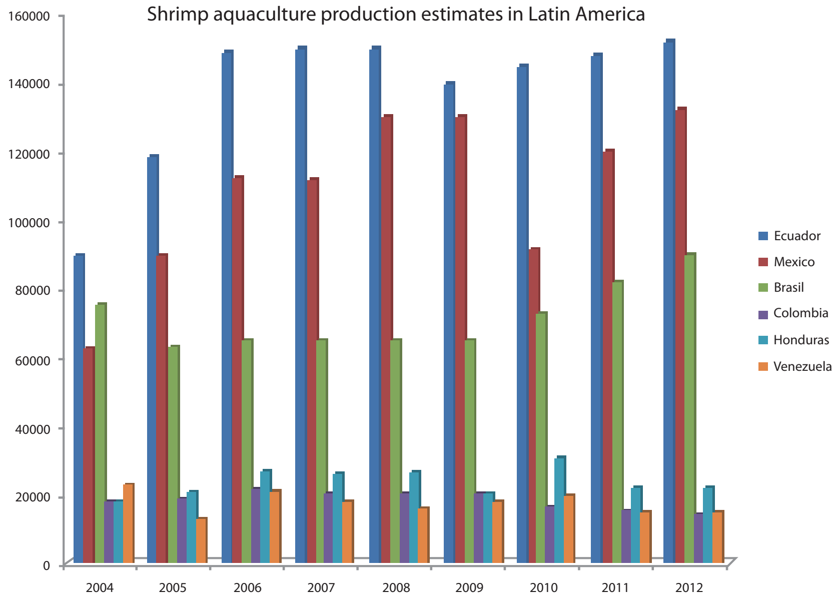
As mentioned before shrimp is the largest single commodity in value terms, accounting for about 15 percent of the total value of internationally traded fishery products in 2010, year in which shrimp demand recovered, after declining in 2009. According to FAO, global production of farm-raised shrimp reached 3.8 mmt in 2010. The Global Aquaculture Alliance survey estimated that production increased by a 0.2% in 2011, but it is probable to decline by some 10.0% in 2012 – down to 3.4 mmt. Diseases in Asia were driving this drop. Nevertheless, production is likely to recover to 3.5 mmt in 2013 and further to 3.8 mmt in 2014. In value terms, the major exporting countries are Thailand, China and Vietnam. The United States of America continues to be the main shrimp consumer and importer, followed by Japan (FAO, 2012). Spain, France, UK and Italy are the main markets in the European Union. The largest importer is Spain, which receives approximately 25% of its imports from Argentina. Germany imports grew by 17% in 2009, and they were mainly originated from Thailand and Vietnam (Atkearney, 2010).

The Latin-American shrimp industry

In this region Ecuador, Brazil and Mexico account for nearly 72% of farmed production. Other producer countries are Colombia, Venezuela and Honduras (Wurmann, Madrid et al., 2004). The Pacific white shrimp has been successfully farmed in Ecuador and other countries in the Western hemisphere. By the mid-1990s, Brazilian farmer organizations developed their own reproduction, larviculture and grow-out technologies based on L. vannamei (Fontinele and deAraújo, 2012).

The figure 2.2 shows shrimp aquaculture production estimates for Latin America from 2004 to 2012. It can be observed that in such period most countries increased slightly their production, while Mexico and Colombia decreased their productivity.
World market prospects for Latin American farmed fishery products are very promising, at least up to 2030, according to the latest available FAO projections. Globally, it is expected that demand progress by about 60 million tons between 2000 and 2030, or a mean of 2 million tons per year. If continued the trend, Brazil is the most obvious regional candidate to become a world leader in farmed shrimp production, because of the availability of adequate sites and land as well as for its natural conditions (Wurmann, Madrid et al., 2004).

Figure 2.2 Shrimp aquaculture production estimates in Asia and Latin America 2004-2012

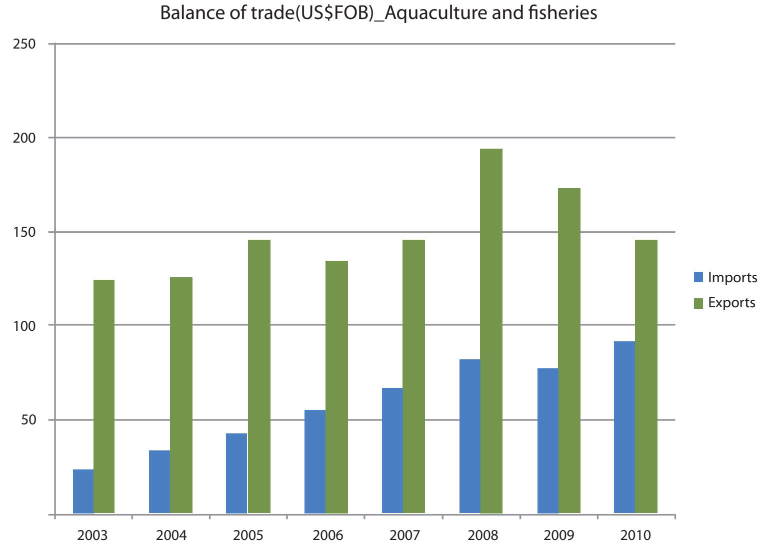


Source: (Jory, 2011)

THE COLOMBIAN SHRIMP INDUSTRY

The fisheries and aquaculture in Colombia are activities that have been gaining importance in the national economy. Regions with these activities include the Caribbean and Pacific coasts, and inland watersheds, especially in the Orinoco, Magdalena, Cauca, San Jorge, Amazonas, Atrato and Sinu. Artisanal, and subsistence fisheries co-exist with small and medium sized enterprises dedicated to capture-based tuna fish, crustaceans like shrimps, lobsters and crabs and some mollusks, as the queen conch and piangua (Salazar, López et al., 2011).
The Figure 2.3 shows the contrast between import and exports of Colombian aquaculture and fisheries sectors between 2003- 2010.

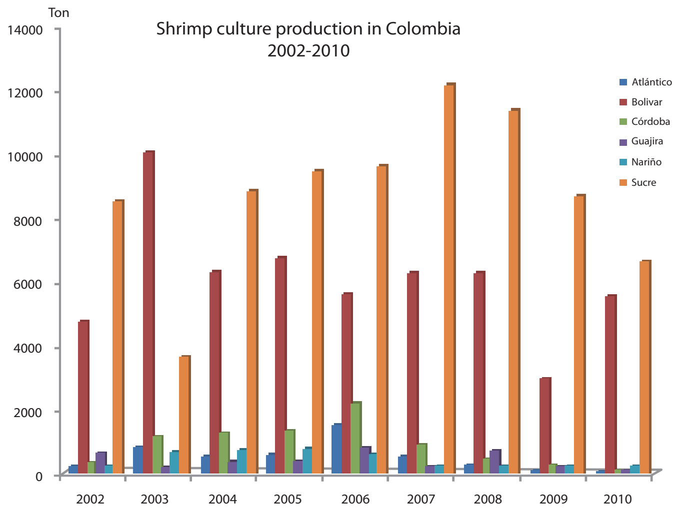
Figure 2.3 Colombian balance of trade, Aquaculture and fisheries sector



Source: DANE, Proexport

Most of the shrimp farms are located on the Caribbean coast in the departments of Atlántico, Bolivar, Cordoba, Sucre and La Guajira. There are also farms on the Pacific coast in the town of Tumaco, Nariño (Duarte, 2002). An important number of farms have been inactive for several years due to problems related to the incidence of white spot syndrome (WSS), and fluctuations of the dollar and the market (Restrepo, Sánchez et al., 2012). Currently, Colombia has improved semi-intensive farming systems with an annual productivity average of 6,000 Kg/ha. Over 7 years, shrimp production in Colombia has grown 20%. During the same period of time, Sucre and Bolivar have consolidated as the primary departments of production, where there is no presence of WSS, and therefore, shrimp farming activities can be developed without harming mangroves. Because the country's sanitary and environmental regulations, Colombian shrimp exports are permitted to almost all countries, and this currently represents over 80% of the national production (PROEXPORT, 2012). Export markets for Colombian shrimp include Spain, France, and the United States. In August 2012, shrimp exports grew 136.6%, having moved from USD 8.7 million in the January-August 2011 period to reach USD 20.7 million for the same period this year (Diaz-Granados, 2012).

Figure 2.4 Colombian shrimp production



Source: FAO, 2011

The following paragraphs give a quick overview of Colombian shrimp industry.

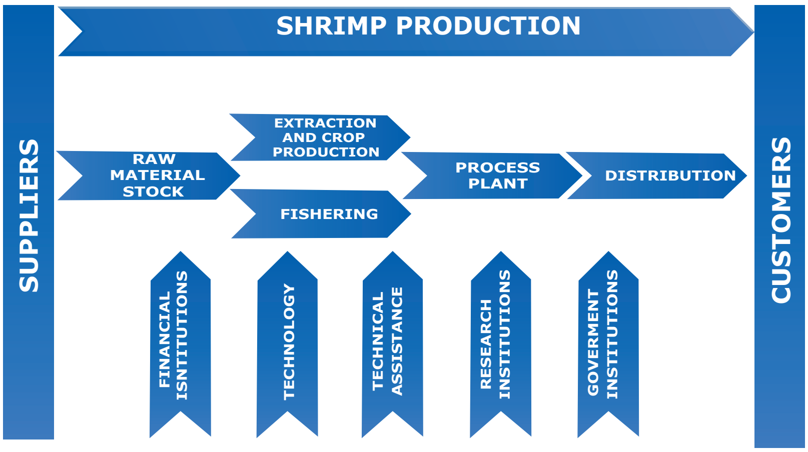
- Costs: The cost structure has been affected by increases in manpower and energy costs (Atkearney, 2010).
- Institutional support: The Colombian Association of Aquaculture and Aquaculture Research Center (Ceniacua) is focused on sanity, genetic, nutrition, sustainability production and diversification. Shrimp farming has been supported by the Ministry of Trade, Industry, and Tourism, through the Productive Transformation Program, PTP. The PTP coordinates with public entities, such as Bancoldex and Proexport, actions to transform shrimp farming into a world class activity. This work has been conducted, jointly, with (CENIACUA). Additionally, Colciencias, the administrative department of science, technology and innovation of Colombia, has one important research strategy: the national program of science, technology and Innovation for aquatic and sea resources.
- Infrastructure: There are ponds (5-8 ha) structure development for extensive production system, however the major production by semi-intensive production system (30-50 shrimp/m2)
- Technological development: The developments in genetics are good in Colombia with world-class laboratories. However, a significant part of the processing and farm some processes are performed manually.
- Regulations: Colombia has not actively participated in setting international standards governing the industry and trade of shrimp in the world, having to take the definitions that dictate other countries.

Colombia's aquaculture sector is considered one of the best organized and most respectful of the country's sanitary and environmental regulations. This is why Colombian shrimp exports are permitted to almost all countries, and this currently represents over 80% of the national production (PROEXPORT, 2012). Export markets for Colombian shrimp include Spain, France, and the United States. In August 2012, shrimp exports grew 136.6%, having moved from USD 8.7 million in the January-August 2011 period to reach USD 20.7 million for the same period this year (Diaz-Granados, 2012).

SHRIMP PRODUCTION CHAIN CHARACTERIZATION

Each link in the production chain involves specific and complex activities and different areas of knowledge and know-how. The main opportunities for learning and innovation are found at these stages of the process (Fontinele and deAraújo, 2012)

Figure 2.5 Value chain shrimp industry



Shrimp production engages a multifaceted system of supply chain where at least four major groups: suppliers, shrimp farmers or producers that use crop production or fishering, processing factories and customers.

Suppliers

The first link in the chain in conformed by the suppliers, which can be classified according to the inputs that provide, as shown (Restrepo, Sánchez et al., 2012):

- Fishing equipment: boats, motors, electronic equipment for detection fishing, mechanical equipment, and general equipment adequacy vessel for seamanship, navigation and maritime security.

- Aquaculture production equipment: ventilators, pumps, feeders, equipment water and soil quality, incubators, laboratory equipment, transporters, minor equipment.
- Process equipment, transformation and accumulation: cold rooms, freezers, ice plants, pilot process plants.
- Transport equipment products live fish or meat: vehicles specialized suitable containers.
- Research teams: boats, laboratory equipment, pilot equipment fishing, computers, etc.
- Fishing gear: all kinds of gear fishing, as gillnets, longlines, seines, variety of lines hand, long-line.
- Materials for fishing and marketing: buoys, wires, ropes, hooks, sinkers, swivels, ropes, gates.
- Aquaculture supplies: concentrates, medicines, fuel, ice, salt, supplements food others.
- Fishing supplies: ice, fuel, baits, plastic bags, boxes cardboard.
- Public service providers, water drinking, port services, services cooling, maintenance and repair of equipment, fishing gear and infrastructure, others.
- Suppliers of spare parts, paints, anticorrosive, and several others.

Extraction and crop production

The producers are the most important link in the chain in fisheries and aquaculture; they use and have a direct impact on ecosystems and their resources (Restrepo, Sánchez et al. 2012). The shrimp farms constitute the primary production stage to obtain shrimp of commercial size and weight (Aguirre, Palau et al. 2008).

Shrimp farming has expanded over the past two decades thanks to dynamic improvements in the production process in several countries, resulting in both technical and managerial innovations. Advances in culture technique include genetic improvement, project design and engineering, nutrition technology, biosafety, inputs and equipment, product processing and, more recently, biotechnology. These changes have boosted productivity and profitability and increased competitiveness on the international market (Fontinele and deAraújo 2012). Genetic modification laboratories have grown in recent years, allowing the higher exports and imports between customers and suppliers. This situation has generated the development local programs that focus in being closer to the customer for more specific conditions of crop genetics. Some international laboratories are trying to participate through alliances with larva producers in target markets (Atkearney 2010).

The crop production process begins in a multiple set of tanks which are designed exclusively for each one of the phases. In the first phase, females and males are housed for mating; after completion this period, females are transferred to the other room for deposit their eggs. In a cycle of 10 to 20 days, the eggs are incubated until converted to nauplii. Upon completion of the ripening period, the seed is carried to larviculture laboratories where is transformed the nauplii to postlarvae. In this stage it should be very careful with the water analysis, fitoplanto, as well as feeding and nutrient application inorganic to stimulate growth (Espinal, Martínez et al. 2005). The larviculture—maturation and postlarvae production includes the selection and preparation of reproducers, mating, spawning and hatching. The growth shrimp stage includes activities such as pond fertilization, liming, physico-chemical water treatment, feed control, biosafety and environmental control to prevent contamination and disease (Fontinele and deAraújo, 2012).

Fishing

For several years, the common denominator the shrimp fishing has been the downward trend in their production but in numerous regions this small-scale fishing continues today, as in China (stow nets), Indonesia (lift nets, push nets, beach seines, gillnets), Mexico (barriers across estuaries), and Madagascar (nets, weirs and traps). Such small-scale fishing is responsible for a surprisingly large proportion of the world's shrimp catch (Gillett, 2008).

Processing plan

After sorting and preparation, shrimp is packaged, frozen and stored until the time of release to the market. There four types of production technologies, which are: the extensive, semi-intensive, intensive and super-intensive cultivation technologies.

The extensive cultivation is done in large ponds whose surface varies from a few hectares to about 100 hectares. This technology has the minimum water exchange and the seeding rate is maximum 15 shrimp per m2. In semi-intensive farming pond size between 1 and 20 hectares, water exchange is between 5% to 20% volume per day and the planting density is 15 to 45 shrimp per m2. Intensive farming is usually done in ponds less than 2 hectares, with intense water exchange by pumping, between 25% and 100% of the volume of water per day are used and densities of more than 45 shrimp per m2 powered with complete fertilization. Finally

the super-intensive type technology is made into closed greenhouse with permanent water replacement. Typical infrastructure area is 280 m2 and uses very high densities ranging from 300 to 450 shrimp per m2 (MADR, FAO et al., 2011).

Advances in production processes-such as culture management and the use of new inputs, materials and equipment-have occurred gradually but slowly. In general, innovations have been restricted to incremental aspects of the main stages of the production process i.e. larviculture, grow-out and processing (Fontinele and deAraújo, 2012).

Processing usually includes selection, washing, classification and freezing of whole (though occasionally beheaded and gutted). It also involves sensory analysis and hazard analysis and critical control point (HACCP) programs to meet food hygiene and safety regulations (Fontinele and deAraújo, 2012).

Shrimp products

This step is performed by post-processing companies. Common shrimp market frozen products comprise:

- Raw head-on shell-on
- Raw headless shell-on
- Raw headless easy peeled
- Cooked headless shell-on
- Cooked peeled and deveined tail-on
- Cooked peeled and undeveined tail-on

Value-added products are classified into several groups, including dried/salted/ in brine, cooked and smoked, and prepared/preserved. There are also sophisticated niche products like pre-battered or coated shrimp, frozen entrees, such as ready-to-eat microwavable meals and organic shrimp.

Packaging, storage and conservation activities must take into account environmental and food safety issues as well as marketing and advertising while wholesale and retail trade involve a number of technical aspects related to customer service, marketing, product presentation and storage, competition and others (Fontinele and deAraújo, 2012).

SHRIMP BYPRODUCTS

The shrimp meat is an excellent source of protein, calcium, the muscle consists of highly unsaturated fatty acids (HUFA) such as eicosapentaenoic (20:5n3, EPA) and docosahexaenoic (22:6n3, DHA) acids, considered as essentials (Sriket, Benjakul et al., 2007). From entire shrimp only 65% is used for human consumption (Núñez-Gastélum, Sánchez-Machado et al., 2011) Chitin, chitosan, glucosamine, carotenoids (mainly astaxanthin) and carotenoprotein have been extracted from shrimp, crab shells, and squid pens. These nutraceutical compounds have a wide range of properties for disease prevention e.g. antimicrobial, anti-inflamatory, antioxidant, antitumor, antiulcer, immunoenhancing, weight and cholesterol reduction (Si and Frans, 2012).

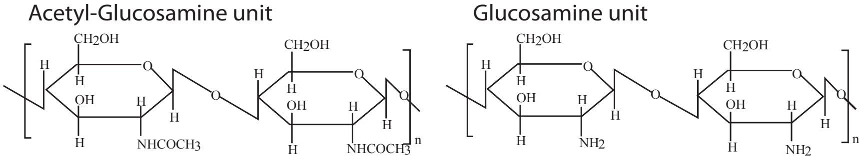
The disposal of these residues could be related to environmental issues because they are source of contamination due to deterioration by microorganisms. An alternative to the conservation and use of these residues is the lactic acid fermentation, which allows to separate the three principals components: chitin, proteins and lipids (Núñez-Gastélum, Sánchez-Machado et al., 2011). From these residues there can also be extracted astaxanthin, the most abundant pigment in crustacean wastes, highly valued as salmonid food, such as rainbow trout in aquaculture systems, and in the cosmetic industry (Armenta, Guerrero-Legarreta et al., 2002)

CHITIN/CHITOSAN

Chitin and chitosan are copolymers of N-acetyl-D-glucosamine and D-glucosamine. The figure 2.6 shows the structure of those biopolymers (Orrego and Salgado, 2011)

Figure 2.6 Idealized structures of chitin (1) and chitin 100% deacetylated (Abdel-Naby). Chitosan

is a copolymer intermediate between (1) and (Abdel-Naby).



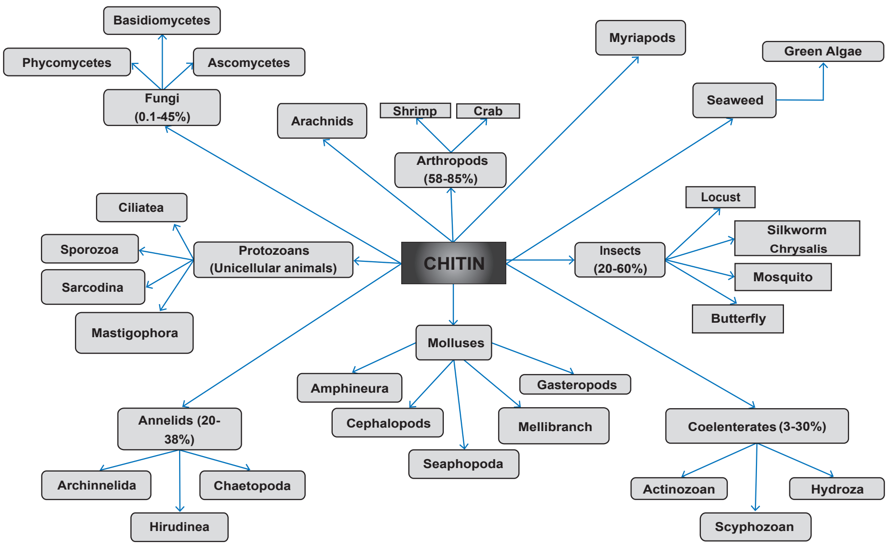
(1) (2)

Chitin is the principal natural organic compound in nature after cellulose, and the largest nitrogen-containing organic compound behind proteins. Even as cellulose is produced mainly from plants, chitin is produced chiefly from animals. It is estimated that approximately 10 billion tons of chitin can be biosynthesized in nature each year (Yao, Li et al., 2011).

Resources

Chitin is present in a wide range of animal species and also in the majority of fungi. Figure 2.7 showed several of these potential resources.

Figure 2.7 Examples of natural chitin sources



Source: (Orrego & Salgado, 2012)

PRODUCTION AND CHARACTERIZATION

Production. Traditional chemical process

Traditional method for the industrial recovery of chitin from shrimp wastes or crustacean shells comprises two steps, deproteinization with alkali and heat and demineralization using mineral acid. While some authors considered that the order of these two phases is exchangeable, other authors suggested that demineralization should be executed first in order.

Table 2 shows a detailed production process for extraction of chitin and its transformation to chitosan. The protocol could be used in laboratory and/or pilot scale. The information reported in Table 2 is a compilation of author's experience in this manufacture process.

Conventional process for chitin extraction begins with the drying of the natural resource (shrimp wastes). This particles are subjected to different process, deproteinization with (0.05- 0.2)N NaOH between 1 to 3 hours. After that the material is soaked and neutralized with distilled water. The deproteinized chitin was demineralized by immersion in HCl (4-6)N during 20 to 30 hours. The resulting solid is then washed with distilled water again until neutrality. Subsequently, raw chitin is deacetyled with NaOH (5N) at a temperature between (100- 130)°C for time enough for definite deacetylation degree is reached. After this step, the chitin or chitosan is washed and submerged in a diluted aqueous solution of acetic acid and sodium chloride during 40 to 60 hours. Finally, after the last wash with water, the chitin/chitosan is filtered, air dried at 60 ° C for 48h, and stored.

Variations of the above mentioned general method has been proposed. Yen et al. (2009) removed the minerals with a treatment with 1 N HCl solution at room temperature for 6 h and then they treated the resulted material with aqueous sodium hydroxide solution at the ratio of 1:10 (w/v) at 100 °C for 3 h to remove protein. For bleaching, the precipitate thus obtained was treated with 1% potassium permanganate solution for 1 h, and then reacted with 1% oxalic acid solution for 1 h. Lastly, for N-deacetylation, 1 g of purified chitin was treated with 30 ml of 40% sodium hydroxide solution at 105 °C for 60, 90 and 120 min, respectively (Yen, Yang et al., 2009).

Table 2 Chitin/ Chitosan production

Activity description	**Symbols**					**Time (min)**	**Quantity**	**Observations**
	○	⇨	D	□	▽			
Pretreatment								
Transportation from the truck to the conveyor belt		●				5	10 Kg	
Transport		●				5	10 Kg	
Harvesting shrimp shell	●					120	10 Kg	Meat removal
Transport		●				10	10 Kg	
Cleaning and disinfection	●					10	10 Kg	
Stay in the wash tank			●			240	10 Kg	
Inspection				●		5	10 Kg	
Transport		●				5	10 Kg	
Drying	●					5	10 Kg	Tray Dryer, 60ºC
Waiting on drying			●			2880	10 Kg	
Transport		●				5	10 Kg	
Crushing	●					15	10 Kg	
Sieving	●					15	9.4 Kg	
Transport		●				5	9.4 Kg	
Storage					●		9.4 Kg	
Transport sterilization tank		●				5	9.4 Kg	
Sterilization	●					5	9.4 Kg	121ºC
Stayin sterilization tank			●			30	9.4 Kg	
Inspection				●		5	9.4 Kg	
Solution removal	●					5	9.4 Kg	Filter
Cooler	●					30	9.4 Kg	30ºC
Transport to deproteinization tank		●				5	9.4 Kg	
Deproteinization								
Washing with NaOH solution	●							30ºC, 0.1N NaOH
Stay in the wash tank			●					30ºC, 0.1N NaOH
Inspection				●				
Solution removal	●							Filter
Transport to neutralization tank		●						
Neutralization								
Washing with water	●							Dionized and destilled water
Waiting in the wash tank			●					Dionized and destilled water
Inspection (pH=7)				●		5	8 Kg	
Removal solution	●					5	8 Kg	Filter
Transport to demineralization tank		●				5	8 Kg	
Demineralization								
Washing with HCl solution	●					5	8 Kg	30ºC, 6N HCl
Waiting in the wash tank			●			1440	8 Kg	30ºC, 6N HCl
Inspection				●		5	8 Kg	
Solution removal	●					5	8 Kg	Filter
Transport to neutralization tank		●				5	6.9 Kg	
Neutralization								
Washing with water	●					5	6.9 Kg	Dionized and destilled water
Stay in the wash tank			●			1440	6.9 Kg	Dionized and destilled water
Inspection (pH=7)				●		5	6.9 Kg	
Solution removal	●					5	6.9 Kg	Filter
Transport to deacetylation tank		●				5	6.9 Kg	
Deacetylation								
Washing with NaOH solution	●							30ºC, 5N NaOH
Stay in the wash tank			●					110ºC, 5N NaOH
Inspection (deacetylation degree)				●				
Solution removal	●							
Transport to deacetylation tank		●						
Washing with sales solution	●					5	5.2 Kg	Acetic acid and sodium salt solution 1%
Stay in the wash tank			●			2880	5.2 Kg	30ºC, Acetic acid and sodium salt solution 1%
Inspection				●		5	5.2 Kg	
Solution removal	●					5	5.2 Kg	Filter

Transport to dryer						5	4.3 Kg	
Drying						5	4.3 Kg	
Waiting on drying						5	4.3 Kg	
Transport						2880	4.3 Kg	
Inspection (moisture content)						5	1g	
Packing						20	4.3 Kg	
Transport						5	4.3 Kg	
Storage							4.3 Kg	

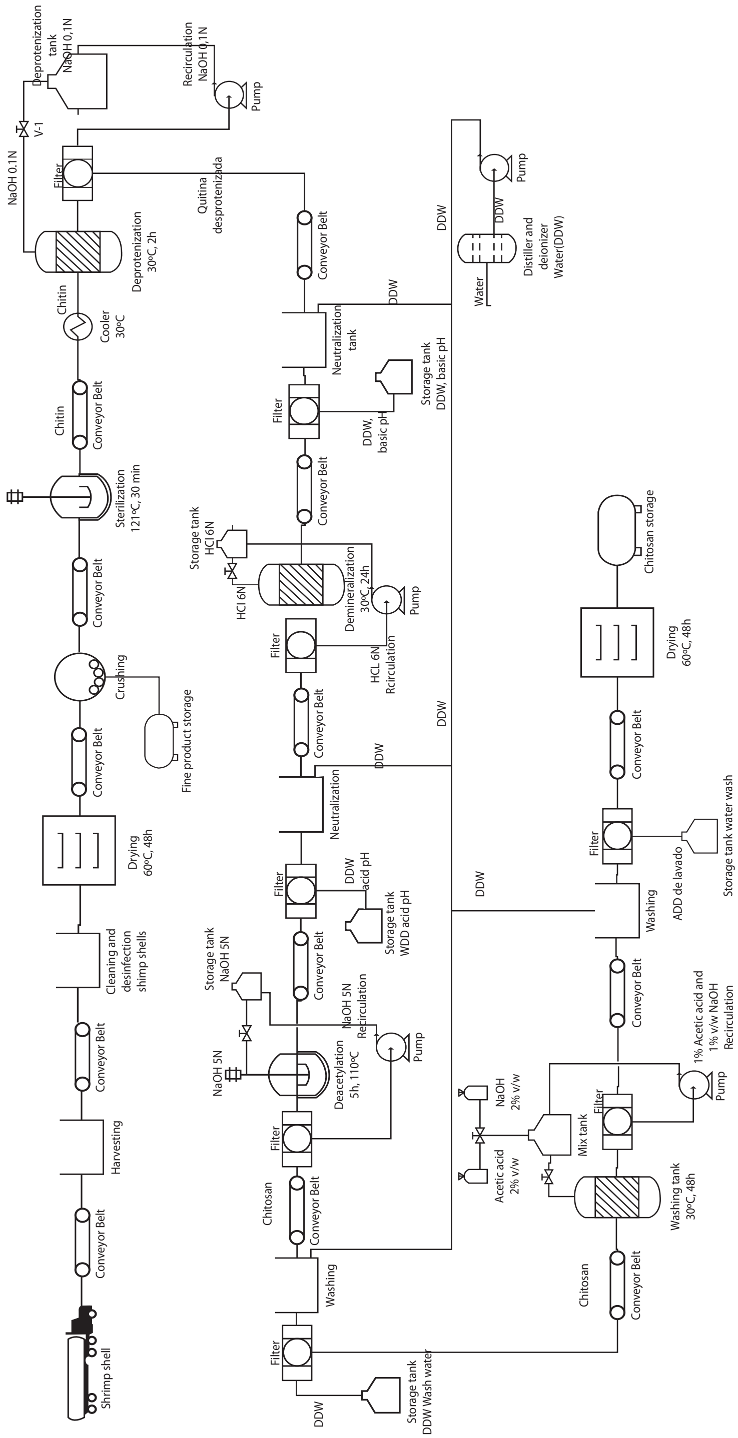


Figure 2.8 Chitin/Chitosan production

Characterization

The principal properties used for chitin/chitosan characterization are:

Solubility
For chitin, owing to its semi-crystalline structure with extensive hydrogen bonding, its solubility parameter is very high and so it is insoluble in most organic solvents (Pillai, Paul et al., 2009) Chitosan is readily soluble in dilute acidic solutions below pH 6.0 (Rinaudo, 2006).

Degree of N-acetylation (DDA)
The DDA is a measure of glucosamine moieties (that carry free amine groups), the fraction of free amine groups, or the positive charge distribution in the chitin/chitosan molecule that will be available for interactions with negatively charged surfaces or compounds. According to this parameter chitosan can be defined as chitin sufficiently deacetylated to form dilute acid soluble salts (DDA 80–85% or higher) resulting in a profusion of amino groups in its molecule that make chitosan a cationic polyelectrolyte, one of the few found in nature (Orrego and Salgado, 2011).

Molecular weight
The molecular weight measurement for chitin/chitosan can be determined by viscometry (Zhou, Chen et al., 2008; Jayakumar, Prabaharan et al., 2010).
Moisture sorption isotherms
Moisture sorption isotherms of chitin and chitosan can be used for the determination of the moisture monolayer content, a measure of the availability of water for an enzyme supported on those materials in non aqueous catalysis. Moisture sorption isotherms of chitin and chitosan can be measurement by static gravimetric method in a laboratory set up consisted of eight glass hermetic flasks, six of them with different saturated salt solutions in their base (LiCl, $MgCl_2$, K_2CO_3, NaCl, KCl and $BaCl_2$). These salts have a range of relative humidity from 5% to 90% (Bizot, Riou et al., 1987).

Surface area measurements
Morphological characteristics of interest are surface area, pore volume, area and pore size distributions. In a work of Orrego et al. (2010) surface area of chitosan beds was measured by means of a sortometer. The results showed that dried chitosan surface areas are strongly influenced by the dehydration procedure (Orrego and Salgado, 2010).

Atomic force microscopy (AFM)
This technique has made possible to characterize surface structures of membranes –surface roughness (Chan and Chen, 2004). For example Nosal et al studied the surface of chitosan membranes and they found that the surface morphology at this scale could be the result of small regions of amorphous polymer

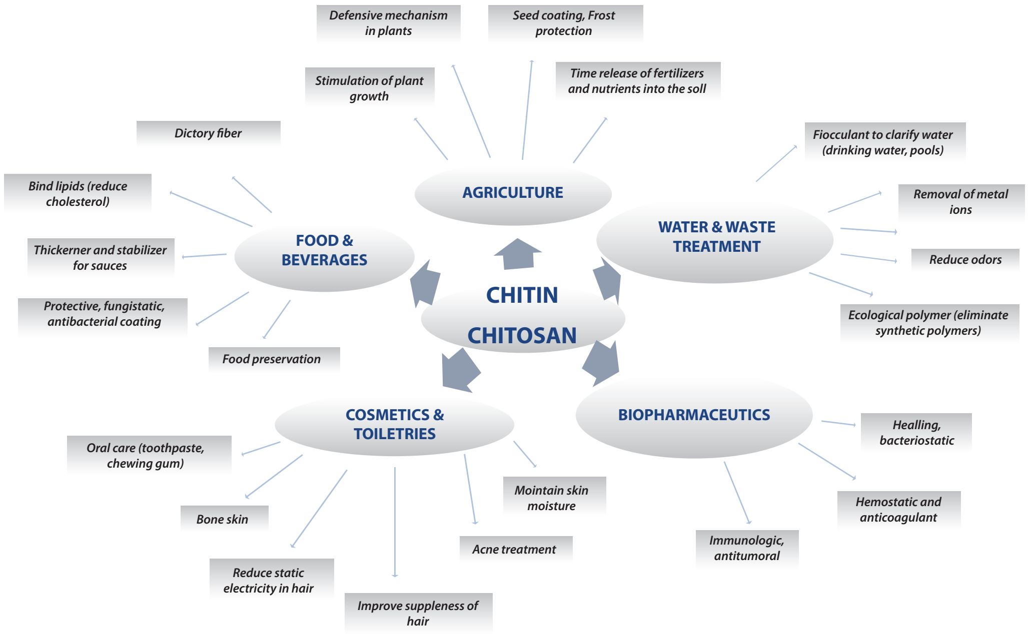
contained within a polycrystalline-like matrix or viceversa (Nosal, Thompson et al., 2005).

Thermal analysis
Thermal methods such as thermogravimetry (TGA), differential scanning calorimetry (DSC) in chitosan had showed that this polymer have two descomposition steps, the first occurs in the range of 50–110°C, and is attributed to water evaporation. The second occurs in the range of 300–400°C and could be attributed to the degradation of the saccharide structure of the molecule (Paulino, Simionato et al. 2006).

INDUSTRIAL USES

Currently, chitin/chitosan have many applications in industrial sectors such as ion exchange media, bacterial immobilizer and absorbent for heavy metal removal.In the food industry, these biopolymers are used for flocculation of proteins and lipids. The more known applications are for biomedical uses for instance in tissue engineering, bandage and wound healing, treatment for burns, ophthalmology and as ingredient in drug delivery systems (UAM, 2011).
The Figure 2.8 shows the variety of the uses of chitin/chitosan.

Figure 2.8 Industrial uses of chitin/chitosan



Source: Orrego and Salgado, 2012

ENVIRONMENTAL IMPACTS

The main environmental impacts in the production of chitin and chitosan are related with the fishery and shrimp industries and the extraction and transformation processes.

Suppliers

Although chitin and chitosan can be extracted from a great variety of resources, for currently commercial production the suppliers are the fishery and shrimp industry which are important greenhouse gases emitters (Grajales-Quintero, 2008)

The environmental impact of shrimp-farming depends on culture method, planting density, feed variety, hydrography of the location and husbandry practices. The use of therapeutants, vitamins and antifoulants and the introduction of pathogens and new genetic strains have also environmental risks (Wu, 1995). Other factors to be considered for evaluating sustainability of shrimp farming or shrimp fishing are (Páez-Osuna, 2005; Gillett, 2008).

- Economic impacts in the marketplace
- The destruction of mangrove forests for shrimp aquaculture operations; erosion coastal, reduction of biodiversity
- Conversion agricultural land by saline soil
- Reduction wild poslarva and biodiversity
- Pollution of water bodies with nutrients, organic matter and sediment
- Salinization of freshwater
- Deterioration in the quality of the receiving waters of the effluent of shrimp ponds
- Spread of diseases
- Loss of biodiversity in ecosystems neighbors

Marine shrimp and fish culture can be sustainable industries, provided pollution loadings generated by fish farms are kept well below the carrying capacity of the water body. Effects can be appreciably reduced by careful location assortment, control of stock planting density, improved feed formulation and integrated culture (Wu, 1995).

In the capture fishery, fuel efficiency is related to the carbon dioxide emissions, the fuel used and the weight of catch achieved. This emission was estimated as 3 Tg of carbon dioxide per million tons of fuel used (Hall, 2011).

EXTRACTION AND TRANSFORMATION PROCESSES

The conventional chemical process for deproteinization, bleaches and deacetylation of the raw resources for chitin chitosan production involves the use of high concentrations of strong acids and bases such as sodium hydroxide and hydrochloric acid as well as large volumes of water, which causes environmental pollution, due to chemical residues with high concentration, addition to the reduction of chemical and biological indices of oxygen in the water Leceta et. al showed in an environmental assessment about the traditional process of extraction of chitosan and packaging production from this material, that the majority of the environmental charge for carcinogens, respiratory inorganics, climate change effects, ecotoxicity and minerals impact categories is due the use of the hydrochloric acid in demineralization stage (Leceta, Guerrero et al., 2013). Also, CO2 releasing also increases the carbon footprint.

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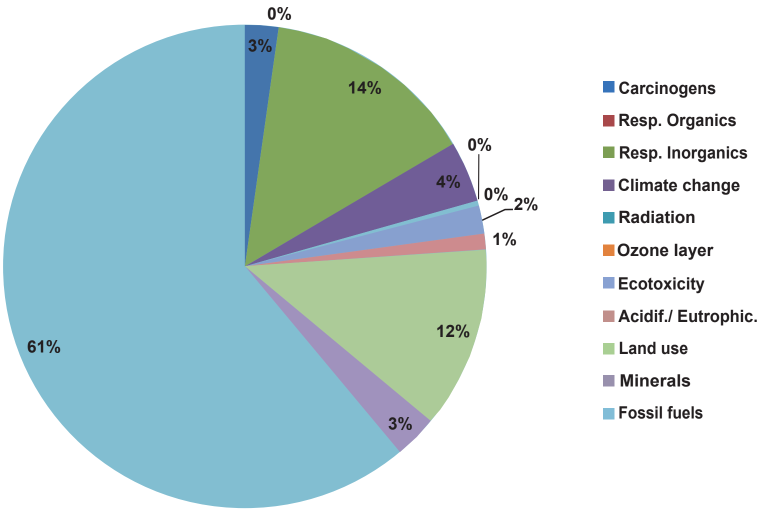
Figure 2.9 Environmental assessment of chitosan traditional production adaptation



Source: Leceta, Guerreo et al., 2013

Chitin, chitosan and derivatives global market

A market study made in 2010 reported that United States and Japan represents the largest markets worldwide for chitin and chitosan, with a participation of 30 and 20 percent respectively. For these countries most successful applications are biomedical, wound dressing materials and artificial sutures. However there are other important demanding industrial sectors such as the paper production, textile finishing, and cement, heavy metal chelating agents, photographic products and waste removal. The study also evaluated the growing market of chitin derivates in the coastal countries by its raw material accessibility with a compound annual growth rate, CAGR, of more than 12.0% over the analysis period. Among derivatives, glucosamine represents the largest segment globally with a representatively of 60 percentage in the market (Orrego and Salgado, 2012). In the European Union the production of natural polymers, including chitin and chitosan was marked by a clearly growing trend over the years 2006-2007 (Wysokińska, 2010).

The major consuming industries of chintin chitosan and derivates are Advanced Biopolymers AS, Biothera Inc., CarboMer Inc., Dalian Xindie Chitin Co. Ltd., HaloSource Inc, Heppe GmbH, Kunpoong Bio Co. Ltd., Meron Biopolymers, Primex Ehf, QBas Co. Ltd., Sonat. Co, Taizhou Candorly Sea Biochemical & Health Products Co. Ltd., and V-Labs Inc (Global_Industry_Analysts_Inc, 2010; Global_Industry_Analysts, 2012; Vasep, 2012).

The increases in prices of these biopolymers depend of high production costs, lack of quality chitin and chitosan available in the market, production shortages, and heavy pollution during the production process (Global Industry Analysts, 2010).

Penetration into new fields represents the key growth driver. So, besides the aforementioned traditional applications, new uses such as agrochemicals are poised to drive future consumption of chitosan. Major issues impacting the chitin & chitosan market include high production costs, lack of quality chitin and chitosan available in the market, production shortages, and heavy pollution during the production process.

GREEN LOGISTICS STRATEGIES IN CHITIN/CHITOSAN INDUSTRY

The earth's climate is changing by the impacts generated with humans activities that may influence the safety of food harvested from marine and freshwater environments. Understanding green logistics as the supply chain management practices and strategies that reduce the environmental and energy footprint of distribution, focused on material handling, waste management, packaging and transport, it is very important to do changes in various links of chitin/chitosan production chain for decreasing energy, water consumption and disposal and, therefore to decrease the carbon footprint and to make a positive score in the life cycle of these products.

Suppliers

There are many detractors of fishing and shrimp farming commercial activities that, although economically viable, can cause negative environmental impact. In fact in a 1997 report entitled "The Shrimp: A Devastating Delight" Greenpeace claimed that "the global development of the shrimp industry is environmentally destructive, inherently unsustainable and inequitable social terms". To fully assess the environmental impacts of the shrimp industry was created in 1997 The Global Aquaculture Alliance, GAA, an international, non-profit trade association dedicated to advancing towards an environmentally and socially responsible aquaculture, recognizes aquaculture as an unique sustainable means of increasing seafood supply to meet the food needs of the world's growing population. Through the development of its Best Aquaculture Practices certification standards, GAA has became the leading standards-setting organization for aquaculture seafood.

To reduce impacts on the shrimp fishery in many fisheries it has been encouraged policies to promote low-impact fuel-efficient fishing strategies. This strategy is increasingly seen as a practical response to rising fuel costs and concerns for ecosystem impacts, potentially delivering gains in fuel use and GHG outputs, improving selectivity and catch value, reducing habitat damage and improving returns (FAO, 2012).

The main environmental concerns related to these industries include the use of large amounts of fresh water for processing, such as for washing raw material and products, cleaning of machines, containers or flushing the working floor and thawing; solid waste production (flesh, shell, bone, cartilage and viscera); consumption of energy for machineries, freezing, cold storage, heating, drying, and water pumping, which contributes to increased air pollution and climate change. Respecting odor and aesthetic damage, odor problems are frequent due to spoiling debris and offal, and improper disposal of solid wastes (Anh, My Dieu et al., 2011). For these reasons the United Nations Organization for Food and Agriculture, FAO, the Network of Aquaculture Centers in Asia-Pacific, the United Nations Environment Program, the World Bank and the World Wide Fund for Nature proposed eight basic principles to achieve a sustainable shrimp production (FAO, 2011).

- Locating culture facilities in adequate environments for making efficient use of land and water resources, and ways that conserve biodiversity, ecologically sensitive habitats and ecosystem functions
- Design culture facilities
- The reduction of water use
- Use known strains of crops to improve biosecurity
- Food Handling
- Health Management
- Food Safety
- Social Responsibility

In addition to these principles, the use of waste of this industry in the production of biopolymers allows to complimentary reduction in the environmental impact

Sustainable production of chitin chitosan and derivatives

Extraction of chitin and its transformation to chitosan is an energy consuming processes and results in environmental difficulties owing to high waste processing costs and the need of neutralization of waste waters. Besides, the low biological value of alkali-recovered proteins might hinder its use in the animal feed industry. Several methods have been reported in the literature to solve such chemical extraction problems in the latest years.

Use of enzyme for tissue protein extraction and recovery

In processing shrimp, the commercialized fraction is approximately 60% (w/w) from which the meat is about 25% (w/w). Roughly 40% (w/w) is solid material containing 25–30% of dry solids. Around 30% of these solids are tissue proteins, while minerals and chitin are the other major fractions. The shrimp waste proteins can be hydrolysed by Alcalase and recovered as a protein hydrolysate. The Alcalase treatment had no undesirable effect on either yield or quality of the chitosan. A large portion of the astaxanthin (usable as high quality shrimp meal) in the shrimp waste can be recovered in the sediment after centrifugation of the crude protein hydrolysate (Gildberg and Stenberg, 2001). One alternative to demineralize the enzymatically deproteinized shrimp waste is using lactic acid and microwave radiation at 400W (Valdez-Peña, Espinoza-Perez et al., 2010).

Chitosan from fungus mycelia

Low molecular weight chitosan (LMW-chitosan) in the molecular range 5–10 kDa could be prepared from the Absidia coerulea mycelia. The LMW-chitosan was obtained after treatments with 2% NaOH and 10% acetic acid. Maximal LMW-chitosan production was 6.12 g/kg substrate. This method provided a new, simple and green technology to produce LMW-chitosan directly (Wang, Du et al., 2008).
For sustainable chitin/chitosan production, existed other methods more environment friendly as:

Fermentation procedure

This process consists in fermenting the sources of chitin with microorganisms in a controlled fermentation process. The main goal of this procedure is the mild mineral removal of the raw material. Sini et al. (2007) studied the production of chitin and chitosan from shrimp shell by using Bacillus subtilis fermentation. They incubated a B. subtilis strain with to 10 mL nutrient broth at 30 °C for 24 h. Thoroughly minced shrimp waste was mixed with 24 h incubated 20% w/w jaggery broth. The flask was tightly closed and kept for fermentation for 15 days. The protease enzyme in Bacillus species was responsible for the deprotenization of the shell, pH, proteolytic activity, extent of demineralization and deprotenization were studied during fermentation. About 84% protein and 72% minerals were removed from shrimp shell after fermentation. Mild acid and alkali treatments were given to produce characteristic chitin. Chitosan from the purified chitin was obtained boiling it 40% (w/w) NaOH until the deacetylated of chitosan was accomplished (Sini, Santhosh et al., 2007).

Duan et al. (2012) studied the waste shrimp fermentation in laboratory and pilot scale with Lactobacillus acidophilus. They took 5mL of starter culture that had prepared by cultivating L. acidophilus SW01 in MRS broth at 37 °C for 18 h. After 100g minced shrimp wastes (not sterilized), 15 g glucose and 10 mL water were put into a 250 mL conical flask and mixed together. Then the flask was covered with an air permeable silica gel stopper and put at 37 °C for 168 h. As a result, the minerals and protein in SW were quickly removed with their contents decreasing to 0.73% and 7.8% respectively after 48 h fermentation. In the pilot scale fermentation, the pH was 3.99 and 3.86 after 12 and 24 h fermentation respectively. The mineral and protein contents were 0.98% and 8.44% respectively after 48 h fermentation. The residue of the fermented shrimp wastes contains less than 1% minerals and can be easily transformed into chitin by a mere bleaching treatment (Duan, Li et al., 2012)

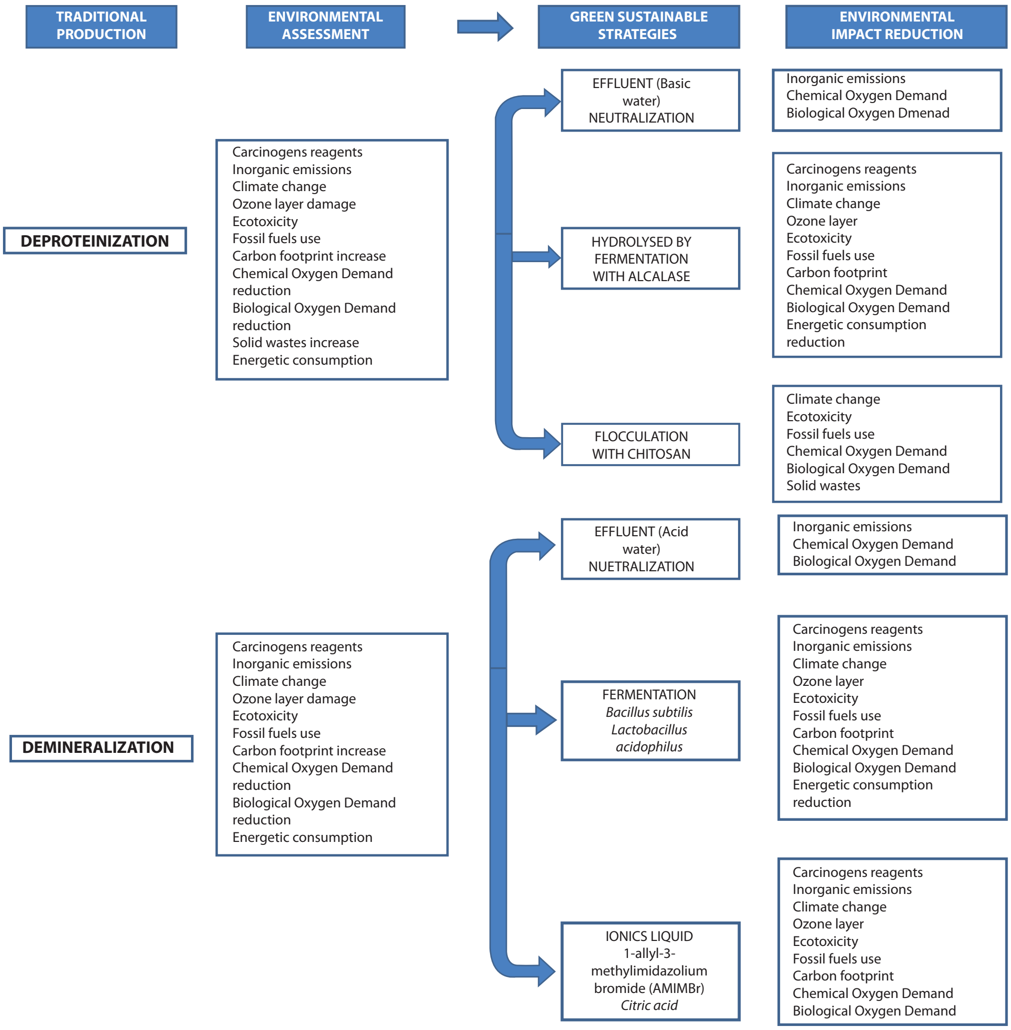
IONICS LIQUIDS

Other technologies that had also been used green chemical process for chitin production involved the employment of ionic liquids. Setoguchi et al. (2012) studied the chitin extraction with ionic liquids and citric acid. Prior to performing the extraction, dried shrimp shells were washed with water, treated with boiling water for 1 h with stirring, and washed with water again. The residues were then filtered, dried, and filtered through a 2-mm mesh sieve to remove small contaminants. A mixture of the pretreated crab shells (2.0 g) and 1-allyl-3-methylimidazolium bromide (AMIMBr) (20 g, 0.098 mol) was heated at 100 °C for 24 h with stirring. After the extraction mixture was subjected to centrifugation, the supernatant (ca. 14 g) was poured into 300 ml of 1.5% (w/v) citric acid (aqueous solution) and the mixture was further stirred for 3 h for demineralization. For this experiments the degree of deacetylation in the samples obtained was calculated to be <7%. Furthermore, the protein content was <0.1% and the molecular weight values were 0.7–2.2 × 10^5 (Setoguchi, Kato et al., 2012).

The implementation of further green strategies in transformation shrimp wastes has had many advantages as the reduction approximately of 50% the use of water during the process, compared with standard process, because the new technology uses water from the raw material, which contain about 75 percent of humidity. Other advantage comes from culturing microorganisms used during the production process because it permitted the remotion the HCL and NaOH solutions, impacting lower costs, also in the waste utilization crustaceans as raw material, which mean a new link in the chain production of crustaceans, integrating fishing industries, aquaculture and processing (UAM, 2011).

The Figure 2.10 shows a qualitative environmental assessment of the activities that generate the major environmental impacts in the production of chitosan. It is also shown the suggestions for lowering these impacts by applying sustainable strategies in the chitin/chitosan extraction process.

Figure 2.10 Sustainable green strategies in chitosan production. Environmental assessment



Customers

The consumers wish to buy products that do not contribute to overfishing or other destructive practices, products certificated as "sustainable". For this reasons there has been creating organizations that are currently actively involved in certifying marine products such as the Marine Aquarium Council, the Global Aquaculture Alliance and the Marine Stewardship Council. The latter is the most widely known example of an independent organization certifying capture fisheries based on standards for sustainable management.

The standard looks at sustainable fishing from three perspectives: the state of the fish stock, the impact of the fishery on the associated ecosystem and the performance of the management system (Gillett, 2008).Ecolabelling can also be a good promoter of sustainability in shrimp fisheries. Some studies of consumer purchasing intentions reveal these trends in the purchasing decisions.

For customers, the price remains as an important factor because chitin, chitosan and derivatives are intermediate products, which serves as a raw material in others industries. Escorcia et. al, calculated the total cost to produce 1kg of chitin from shrimp shell and shrimp head with standard process, the results showed that cost is US$30.98 and from shrimp head is US$135.94 (Escorcia, Hernández et al., 2009). While, Castillo et al evaluated the total structure of cost, where found that for produce 1Kg of chitin, the costs can be discriminated as, US$ 1.94 only production cost, US$11.59 including cost production, the necessary costs to bring the product to the market, initial investment and working capital (González, Morgan et al., 2005).

CONCLUSIONS

Reverse logistics is a constant process and an important part of the logistical chain of shrimp industry. Although it has received growing attention it is still an unexploited opportunity that can have a concrete impact on environment, customers, and earnings.

Shrimp is the largest single commodity in value terms of the total value of internationally traded fishery products. The shrimp aquaculture provide most of this product to the global market, as the shrimp production by fishing in marine resources decreased because of overexploitation. The major exporting countries are Thailand, China and Viet Nam and the main consumers are the United States and Japan. In latin America Ecuador, Brazil, Mexico, Colombia, Venezuela and Honduras are producer countries.

Shrimp production supply chain includes at least four major groups: suppliers, shrimp farmers or producers that use crop production or fishering, processing factories and customers. The growth shrimp stage includes activities such as pond fertilization, liming, physico-chemical water treatment, feed control, biosafety and environmental control. Besides the conventional frozen shrimp products, consumers are currently interested in new value-added products like cooked, smoked, and prepared/preserved shrimps. There are also sophisticated niche products like pre-battered or coated shrimp, frozen entrees, such as ready-to-eat microwavable meals and organic shrimp.

The environmental impact of shrimp-farming depends on culture method, planting density, feed variety, hydrography of the location and husbandry practices. The use of therapeutants, vitamins and antifoulants and the introduction of pathogens and new genetic strains have environmental risks.

From entire shrimp only one fraction is commercialized for human consumption. Residues from shrimp conditioning and consuming contains tissue proteins, minerals and chitin. The conventional chemical process for deproteinization, bleaches and deacetylation these residues for chitin chitosan production involves the use of high concentrations of strong acids and bases as well as large volumes of water, which causes environmental pollution.

Although, the chitin, chitosan and derivatives demand are currently increasing there are constraining growth factors like high production costs, limited availability of high-quality raw material and environmental impact of processing. The use of new green strategies for transformation shrimp wastes (biocatalysis and innovative separation processes) reduce the use of water, HCl and NaOH strong solutions, impacting positively the environment and, in de middle term, not only could increase economic retributions to supply chain actors, but also could allow them to get other intangible benefits such as image and reputation enhancement.

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CHAPTER 3

TOWARDS GREEN SUPPLY CHAIN MANAGEMENT IN AGRICULTURAL SECTOR: APPROACH TO LOGISTIC DESIGN FOR UTILIZATION OF BANANA-PLANTAIN PSEUDO-STEM FIBER

Lady Joana Rodríguez Sepúlveda
Carlos E. Orrego A

Universidad Nacional de Colombia Sede Manizales

INTRODUCTION

Concerns about contamination of renewable resources, the depletion of non-renewable resources, climate change, among others, have resulted in growing of society's environmental conscience. Government regulations in many countries have encouraging research in the development of clean energy options, products and processes with an ecological approach. Alternatives based on concepts such as product eco-design, re-ordering of the supply chain (Capuz Rizo et al., 2006) and cleaner production systems (Hoof et al., 2008) show how to generate options for contributing to sustainable development, with the purpose of conscious design of product life cycle and so reduce its environmental impact.

In this context, natural materials such as flax, hemp, sisal, jute, sisal, etc.., are projected as green products. These fibers, as well as being used since ancient times, are currently studied as an alternative to synthetic fibers in composites for the automotive and construction industries, since these materials are characterized as sustainable options, renewable, inexpensive, biodegradable and usable in corporate responsibility programs.

Annual production of fique (Furcraea andina), considered by some people as Colombian national natural fiber, was about 23.960 tons. In 2010 the main producer departaments were Cauca, Nariño, Santander and Antioquia, which together accounted for 97.8% of total national production (Agronet, 2010). Paradoxically alternative sources of natural fiber are currently ignored. Colombia is one of the major world producers of banana and plantain, plantations in which more than 75% of produced biomass are wasted (Rodríguez & Suarez, 2010). Pseudo-stem banana-plantain fiber, BPF, has comparable characteristics to more known jute and sisal fiber. Despite the extraction for BPF is similar to fique processing, it is far for being a recognized natural fiber option. BPF is produced by a few artisans in regions like Quindío and Caicedonia (Valle). Probably it would be necessary to do more coverage of this potential and its commercial and industrial applications.

In this chapter it is first described the extraction process by using a shredder machine for obtaining BPF from crop residues. This is the recycling primary step of green logistic chain for banana-plantain commercial cultivars (Díaz et al., 2004). After that it is shown the results of a survey with farm producers for estimate the raw material availability in the Manizales municipality. Next, and according to the gravity center methodology, it is evaluated the placement of fiber stocking centers for each of the four production corregimientos in which the rural zone of Manizales has banana-plantain cultivated areas. Finally, there are described some applications and results of chemical modifications of banana-plantain fiber.

BANANA-PLANTAIN

Currently, only two species are of commercial importance: Musa paradisiaca (plantain) and Musa sapentium (banana) (Champion, 1976). Plantain is harvested 15-18 months after planting in template climate. The stems continue to emerge from a single plant every year, making the banana/plantain a perennial crop (Champion, 1976). Banana and plantain are together the fourth most important crop in the world, after rice, wheat, and corn. They are grown in Colombia throughout the country in which generates a lot of direct and indirect jobs.

GLOBAL AND NATIONAL PRODUCTION

India is the world's largest producer of bananas, with 28% of global production, followed by Brazil and Ecuador with 19% and 15% respectively. In most banana-plantain producing countries, production is solely for national consume and it is estimated that only around 21% are traded globally. Although Colombia only produces between 4 to 6% it is the fourth exporter country behind Ecuador, Costa Rica y Filipinas (FAO; Soto, 2011). Global productions of banana and plantain have increased by 175% and 60% respectively over the last 30 years. Their total world production, with over 130 million tons (2010) and ranks fourth after maize, rice and wheat. Only 10-15 % of global production of banana and plantain is exported annually and they international trade, which is dominated by Latin American countries, is worth an estimated $5 billion annually. Taking together, they are the most traded fruit in the world in terms of volume while simultaneously provide food security and income for small-scale farmers who represent the majority of producers (Adam Prakash & Stigler, 2012).

Banana and plantain accounts for 1.6% of the Colombian exports (US$743 million (Proexport_Colombia). Currently, there are estimated to be more than 400,000 hectares with these plantations, from which over 50% are in the coffee growers region, whose production is about 1.7 million tons per year (Espinal G et al., 2006). Caldas department ranked seventh nationally with a production of 261032.3 tons in 2006 (Espinal G et al., 2006). The banana and plantain plantations make a traditional and important sector in the rural economy from the point of view of food security and employment generation. The crop generates about 286,000 direct jobs per year, which is about 57 thousand families (Agronet, 2010; Corpoica; Ministerio de agricultura y desarrollo rural, 2002)

PLANTAIN CHAIN CHARACTERIZATION IN MANIZALES

One of the activities of the introduction to research project "Assessment, analysis and formulation of alternatives for plantain value chain in Manizales aimed at plantain fiber packaging production" was a cultivated area evaluation for integral plant use. As a result, information showed that most plantations belong to small farmers (68.2% of farms does not exceed 8.31 hectares), banana and plantain were associated with another crop and low technical efficiency of production. These findings were related to low economic status and lack of farmers' knowledge of their own culture and use of post-harvest residues.

The crop cycle starts with obtaining the seed, which is obtained by desuckering (the term used to describe the practice of destroying unwanted suckers which develop on the banana plant) or is purchased at an approximate cost of US$ 0.29. Plant crop cycle is of approximately 10 months during which, at the time of the survey, required as average three day laborers per small farm with a daily wage of US$ 11.57. The required raw materials (sprayer, organic matter and seed) constitute 45% of total costs of cultivation. Manual labor accounts for about 39% of labor costs which includes collection, packing and wrapping.

Pests and diseases are a critical factor in sustaining crop. It was estimated that 64% of crops have at least 3 diseases or pests. This fact has high impact on crop economics, together with fertilizer and maintenance costs, crop losses and low selling price at harvest. Farmer owners of small farms do not handle the costs of cultivation, therefore do not show the real income generated from their farms.

OPERATION AND MARKETING

Most producers are crop-economically dependent and some of them commercialize their production. Among the farms surveyed, 68% have plantain as main marketed product, at an average selling price of US$ 15.09 per bunch.

Respondents stated that the marketplace of Manizales, the capital of the Department of Caldas, is the distribution center in which the main trade of plantain regional production is made (60%). It is followed by broker channels (14%) and other portions are commercialized in other cities like Medellin and Cali (13%), or other points of concentration of agricultural trade in Manizales. The roads used for transportation are in good condition according to 82% of farmers surveyed.

Regarding the crop residues such as husk, pseudostem, straw, leaf, stem, root and flower buds, are mainly used for organic fertilization and animal foodstuff. A little fraction of these materials are disposed and others, like the root are left on the cultivated area. None of surveyed farmers had ever sold (nor plan to) any of these discarded materials.

VEGETABLE NATURAL FIBERS

Natural fibers cover a wide range of vegetable, animal, and mineral fibers. Vegetable natural fibers are biopolymeric composites conformed mainly by cellulose, hemicellulose, lignin and waxes. They can be described as fibrils of cellulose immersed in a hemicellulose-lignin matrix. Cellulose fibrils, aligned along the fiber, are responsible of flexural and stress resistance and whole fiber stiffness (Jawaid & Abdul Khalil, 2011; John & Thomas, 2008).

OVERVIEW OF WORLD VEGETABLE NATURAL FIBER

Natural fibers such as flax and cotton have been used since ancient times for textile use. Currently, these and other fibers like jute, sisal and hemp are progressively used for composite materials and several studies are presently proceeding to extend their applications and replace glass and carbon fibers in composites. In 2009 annual production of natural fibers was about 23 million tonnes in contrast to 47 million tonnes of artificial fibers (FAO 2009). Synthetic fibers are highly abrasive and usually contaminants. In contrast, natural fibers are characterized to be healthy, renewable, sustainable and biodegradable. Additionally, the increase in demand for these fibers will certainly benefit thousands of small scale farmers in developing countries.

Within the huge collection of natural plant fibers there are only about 15 with worldwide recognition, with production schemes and fully established distribution logistics, usually supported by government institutions for the promotion and regulation of production (FAO). The fibers of vegetable origin are classified according to the part of the plant from which they are extracted as leaves, seeds or stem. Flax, hemp, jute and banana-plantain are examples of stem extracted fibers.

Cotton

Cotton, extracted from the plant's seed pod, is the most important natural fiber. Its global cultivation area and production are estimated at approximately 30-31 million hectares and 20 million tons respectively. Around 80 countries produce cotton. Among them the most important cotton-growing countries are China, USA, India, Pakistan, Uzbekistan, Brazil, and Turkey (RedTextil_Argentina). Most cotton is used in textile industry, home furniture, upholstery, medical and hygiene supplies, etc (Dam, 2008).

The usually considered cotton processing operations are growing and harvesting; ginning; opening, cleaning and picking; carding, drawing and roving; spinning, winding and twisting; spooling, beaming and slashing and weaving (CDC).

Jute

Jute is a very common vegetable fiber and the second most important fiber produced worldwide. The main producing countries are Bangladesh and India. It is similar to plantain fiber, having high specific strength and stiffness. Originally, jute fiber was used as reinforcement for thermosetting materials. Lately, this fiber has also been successfully used as reinforcing fiber for thermoplastic materials. It is also used for agricultural products packaging, rigid packaging, manufacturing carpets, carpet backings, rugs, tarpaulins, upholstery, ropes, strings, substitute for wood and paper pulp, geo and agro textiles, textiles as burlap, and can be mixed with wool (IJSG; INFOCOMM_(UCTAD); NJB) (Dam, 2008).

The jute fiber is extracted by retting from the stem and outer skin of the jute plant. The retting process consists of bundling jute stems together and immersing them in slow running water in open water (lakes, rivers, ditches, canals and ponds). Microorganisms make controlled decomposition of the non-fibrous materials linking the fibers to the bark of the plants. After the retting process, the manual stripping of fibrous matter is extracted manually, washed in clean water and sun-dried. After that, yellowish white, yellow or brown fibers from 1 to 4 meters long are ready for market (FAO, 1998).

Sisal

Sisal is a coarse fiber obtained from the Agave cactus plant (Agave sisalana) native of Mexico. It is being increasingly used in composite materials for cars, furniture and construction as well as in plastics and paper products, ropes, string, wire and paper.

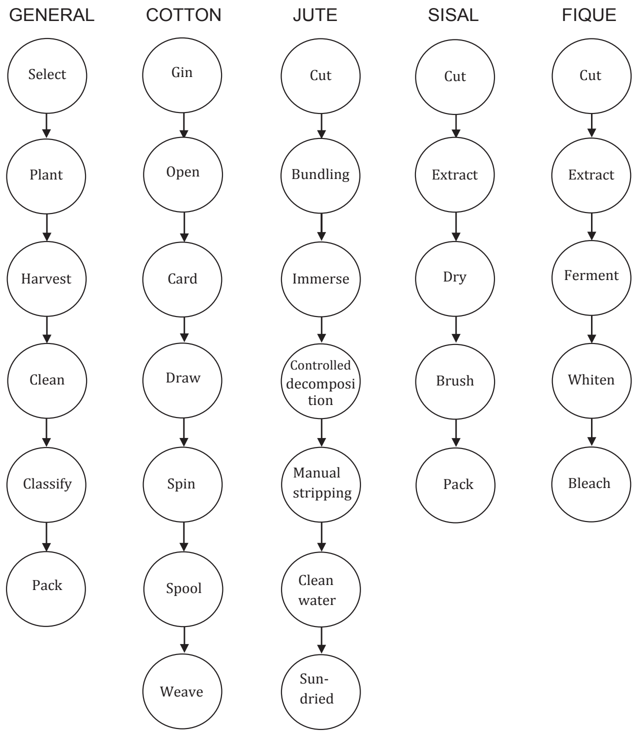
Sisal fibre is extracted by a process known as decortication, where leaves are crushed and beaten by a rotating wheel set with blunt knives, so that only fibers remain. The fiber is then dried, brushed and baled for export.

Artificial drying has been found to result in generally better grades of fiber than sun drying, but is not feasible in the developing countries where sisal is produced. Dry fibers are machine combed and sorted into various grades, largely on the basis of the previous in-field separation of leaves into size groups (WorldJute).

PRODUCTION PROCESS

Figure 3.1 shows a comparative step diagram for the production of the above mentioned fibers. The production process of the fibers is generally divided into two phases: planting-harvesting and extraction-conditioning. Setting aside the operations post-processing (transport, commercialization, etc.) it can be found between 5 and 7 major steps.

Figure. 3.1 Precedence diagram of production process of natural fibers: general, cotton, jute, sisal y fique.



MAIN WORLD FIBER PRODUCTION VOLUME AND PRICE

The world fiber market with a volume over 80.0 million tons is dominated by oil-based synthetic fibers (share ca. 61%). Cellulosic fibers which consist mainly of cotton with approx. 32% of volume and man-made cellulose fibers (ca. 6.1%). The smallest share of the global fiber market is for wool with approx. 1.3%. Table 3.1 shows the amount (tons per year) and prices (US$) of cotton, jute, sisal and two artificial fibers. The higher production volume corresponds to synthetic fibers while the upper price is for cotton. Jute output is around 10% while sisal is only 1.3% of the annual volume of cotton production.

Table 3.1 Production quantities and prices of cotton, jute, sisal and synthetic fibers.

Natural Fibers (NF)	Tonnes/year	USD/ton
Cotton	20.700.000 - 25.000.000 (1)	1886.68 (4)
Jute	2.500.000-3.000.000 (2)	300 (5)
Sisal	300.000 (2)	900 (5)
Synthetic	47.300.000 (3)	1633 (7)
Glass fiber		1390-2000 (6)
Mean NF		600-1500 (6)

(1) (RedTextil_Argentina), (2) (Dam, 2008), (3)(Srtepc), (4) (IndexMundi), (5)(FAO), (6) (Satyanarayana et al., 2007) (7) Polyester (major trade synthetic fiber (Robinson).

COLOMBIAN NATURAL FIBER: FIQUE

Colombia is the largest producer of fique in the world. Besides its main use as sacks and packages for agriculture, fique fiber is consumed for the manufacture of many products such as handcrafts, purses, bags, handbags, mattresses, curtains, shoes, umbrellas, baskets among others. The main fiber consumer companies in Colombia are: La Compañía de empaques S.A., Empaques del Cauca S.A., Ecofibras Ltda, Coohilados del Fonce Ltda, Hilanderías de Colombia and artisans from Nariño, Cauca, Boyacá and Santander. In 2006 they requested 29.2% more than the national natural fiber supply, having to import sisal, jute and other fibers (Ministerio_de_Ambiente, 2006). For this reason it was necessary to make government agreements for encouraging the production and competitiveness of the sector that include guidelines for clean and friendly to the environment production. In Table 3.2 is shown the Departament´s annual production of fique during 2010.

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Table 3.2 State (Departament) annual production of fique in Colombia in 2010.

Departament	Antioquia	Boyacá	Caldas	Cauca	Nariño	Norte de Santander	Risaralda	Santander
Producction (ton)	2356	92	204	10349	7987	150	65	2756

(Agronet, 2010)

Similar to the aforesaid planting and harvesting of natural fibers, the process begins with land preparation and sowing of the seeds. During the growth and maturation of the plant it is necessary to perform maintenance activities such as weeding and fertilizing. The steps for harvesting are: (see precedence diagram in Figure 3.1).

1. Cut the leaves: the farmer groups them, transported and stored at the site of the shredder machine.
2. Extract the fiber: long fiber is obtained, bagasse and juice (in Table 3.3 shows the main application).
3. Ferment to reduce moisture, dry combing and ensuring the removal of debris.
4. Bleach: fiber obtained is known as cabuya.
5. This fiber is classified according to the NTC 992, at which rate the quality fibers that have loose fibers and free of impurities.

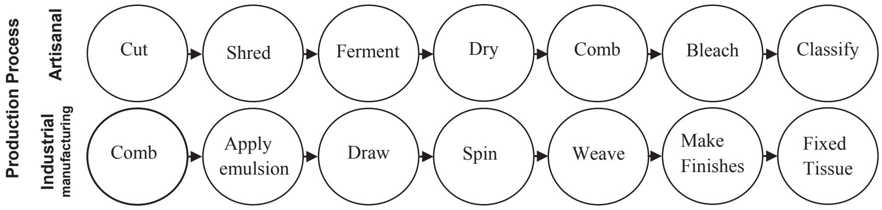
For commercializing the fibers are classified according to Colombian Technical Standad NTC 992, arranged in bundles of 1 or 2 kg which are packaged in 50 kg bags for sale.

Table 3.3 Major uses of fique fiber and its by products.

Long fiber	Biomantos, agrotextiles, oleophilic, thread, packaging, crafts, plush, rope, cloth, leather, etc.
Bagasse	Short fiber paper, fiber reinforced, bonded, mattress ticking, thermal insulation, green moss.
Juice	Potential raw material for sapogenins production.

At present there are two ways of processing to add value to the fiber: the artisanal and industrial (Cano Saenz & Santos Calderón, 2004), the Fig. 3.2 shows two process. The process traditional or artisanal, benefit around 11,200 people per year, in the different departments (Agroindustriahoy, 2009). They use rudimentary looms and spinning individual with electric or manual spinning wheels for yarn production and packaging for agricultural goods (Agroindustriahoy, 2009). The industrial processing has around 934 jobs in the principal four companies. Fifty percent of annual production of fique is used in sacks and packages for agriculture. The main companies in this sector in Colombia are: Compañia de Empaques S.A. (market share 26.7%), Empaques de Cauca S.A. (market share 16.7%), Coohilados del Fonce Ltda. (market share 6.6%) and Hilanderías de Colombia (Cruz Hemida & Medina Terán, 2008).

Figure.3.2 Precedence diagram for two links in adding value to the fique fiber.



Source: Agroindustriahoy, 2009; Espinal G et al., 2006

FIQUE INDUSTRIAL PRODUCTION PROCESS

The Compañia de Empaques S.A. is located in Medellin. In this company the fiber is at first quality checked and classified. Then it is stored for a period of three months before entering to the production process. After that raw material is processed according to these operations:

1. Mechanical preparation: The fiber is impregnated with a water-based and oil emulsion and combed to remove impurities.
2. Stretching: The fiber is stretched to ensure wick yarn.
3. Spinning: By using a spinning machine the threads become more resistant. The resulting yarns are coiled in spools.
4. Coning machining: The yarns are passing to cones with a capacity of with eight spools (7.200m/cone)
5. Knitting: The yarn is knitting by looms according to the reference.
6. Finishing: Knitted fabric is checked for imperfections.
7. Calendering: In a calendar machine the fabric is finished for better smoothness and density.
8. Final product manufacture: The fique fabric is transformed in sacks, packages, geo-and agro texiles, etc.

Fique, coir, sisal and other fibers are used for Compañia de Empaques S.A. to manufacture of films called plushes, for mattress industries such as Industrias Spring S.A., El Dorado and Americana de Colchones. The type of fiber demanded is a high quality fiber, 110 cm length, often imported from other countries in South America

The fique fibers have two direct competitors in the domestic and global market: jute and sisal. Fique fiber is 2% cheaper than sisal and 11% than the jute (Cano Saenz & Santos Calderón, 2004). La compañia de empaques S.A. established a purchase price according to the quality of fique (Fundación_Codesarrollo, 2007): high quality (length 110 cm): US$ 0.82/Kg, ordinary quality (length 70 - 110): US$ 0.68 /Kg, Short: US$ 0.30/Kg without separate US$ 0.67 /Kg and waste US$ 0.30/Kg.

Most agro-textile and packaging products and are exported to Mexico, United States, Costa Rica, Peru, Ecuador and Venezuela. At the end of the product cycle the fibers are biodegradable and can be reused as a carbon source for in the form of carbohydrates, lignin or nitrogen (Fundación_Codesarrollo, 2007).

The fique production chain was consolidated in 2004, with an agreement between governments and Fique Producers Associations, Artisan Associations and Managers of some companies. The main object is promote is to improve the quality of fique and fique products through the development of innovative, integrated and sustainable production chains of high quality fique products that match consumer demands.

APPROACH TO LOGISTIC DESIGN FOR PRODUCTION AND TRANSPORT OF BANANA-PLANTAIN FIBER

Forward logistics for banana plantain fruits and fruit derived products is a network of facilities and distribution options that performs the functions of procurement of fruits, distribution in fresh and transformation of them into intermediate and finished products. In contrast reverse logistic is a supply chain that is redesigned to efficiently manage the flow of products for reprocessing, reuse, recycling or destruction, using all its resources efficiently. This supply chain generates social and environmental benefits, due to creation of economic alternative resources to farmers and by use residues as potential clean and renewable raw materials (Dowlatshahi (cited by Díaz (Díaz et al., 2004)).

The production of plantain/banana fruits as well as the natural fibers mentioned above is then considered as forward logistics (see Fig. 3.3a), while post harvest residues management to produce value added products could be intended as reverse logistics (Fig. 3.3b).

In this section, it is briefly described the production and distribution of banana/plantain fruits in the municipality of Manizales. There are also depicted the main unexploited residues after harvesting banana-plantain crops. However, the focus of the reverse logistics proposal developed here is the use of the pseudo-stem as a source of natural fiber. With that aim there were estimated the fiber potential production harmonized with the suggested location of four fiber stocking centers. Finally it was also presented a preliminary approach to the alternative farmers income for exploitation of such fiber in the rural area of Manizales.

FORWARD CHAIN LOGISTICS FOR FRUIT PRODUCTION

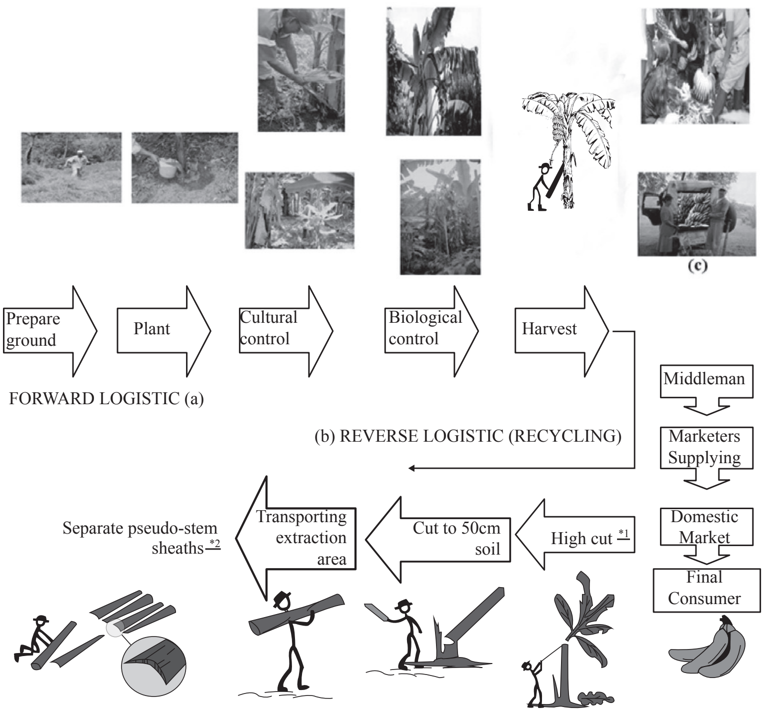
There are four main operations in banana-plantain fruit production: planting and harvesting by primary producers, supplying of domestic market (direct from producers to retail or indirect by merchant and broker intermediation), exporting and value added manufacturing. Planting and harvesting cycle lasts 10-12 months and include steps like land preparation, planting, cultivation, maintenance, pest and disease control and harvest (Belalcázar et al., 1991).

In marketing, farmers sell their product to a middleman in his property or in marketplace. The initial selling price depends on the quality of the product, with a cost/unit as follows: if it's good quality and bagging for markets of Bogota and Medellin is purchased at a price of US$ 0.38/unit, if the banana is average quality is sold in the marketplace to a wholesaler between US$ 0.25 and US$ 0.30 per unit, but without bagging. If the quality is very low, farmers prefer its consumption or for animals. The wholesaler distributes the product to retail stores and -subsequent or final consumer Fig. 3.3c. Some products are processed in the agribusiness in producing dehydrated or frozen banana, snacks, flour or concentrated animal feeding (Espinal G et al., 2006).

REVERSE SUPPLY CHAIN FOR BANANA/PLANTAIN FIBER

the activities of the reverse logistics to banana plantain chain are:

Figure 3.3 (a) Forward logistics for platain/banana product production, (b) reverse logistics for platain/banana fiber production and (c) commercialization platain/banana product.

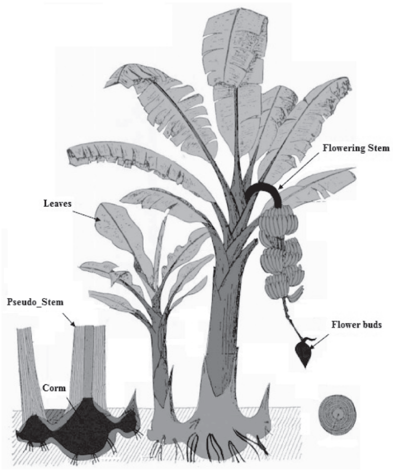


Source: Adapting from Beaulieu (Díaz et al., 2004)

1. Separation of banana-plantain crop residues.
2. Sorting / grouping of these residues or materials for transport.
3. Transportation to intermediate treatments
4. Intermediate treatments: Activities for preparing the materials for retreatment. In the case of banana plantain fiber this stage is the fiber extraction from the pseudo-stem.
5. Retreatment: Manufacture of fabrics, artisan-crafts, composites and other high value-added products. It could be included surface chemical treatments of fibers.

Plantain production generates approximately 75% of waste. This material is generally left in the place of harvest. Reverse chain supply for the potential use of this biomass starts in the moment of harvest. The plant is separated into leaves, stem, pseudo-stem, corm and flower buds. In Fig. 3.4 (Fig.3.3*1) are schematically shown the post-harvest residues of plantain plants and the recycling stages proposes for the production of pseudo-stem fibers (Arcila, 2002; Mohapatret al., 2010)

Figure. 3.4 (Fig 3.3*1): Morphology of Plantain.



Plant part	Potential byproducts
Corm	Compost Fertilizers, animal feed
Flower buds	Food (cakes) Floral Ornaments
Pseudo_Stem	Fiber Animal feed Paper Agglomerates Tannic liquor
Leaves	Ethnic food packing (tamal) Animal feedl
Flowering Stem	Paper Food (chips) Preparation of jams

Source: Adapted Champion, 1978. Full use of the plant.

In contrast with the forward logistics production steps described above for other natural fibers (cotton, jute, sisal and fique) the proposed recovery scheme showed in Fig 3.1, is a reverse logistic supply chain which aims to the use of a renewable natural resource with low energy consumption and carbon print reduction. Growing natural fiber depends mainly on solar power and for its extraction zero or minimal amounts of fossil fuel energy are required. Comparatively, the production of the same quantity of fiberglass could require between 5-10 times more of non-renewable energy (Joshi et al., 2004).

Alternatively, the activities for production banana-plantain could be understood as recycling or recoveries which are defined as the set of activities that add value during the transformation process, converting returned products and parts in recycled or re-manufactured goods. Recycling involves disassembly, sorting and processing of raw materials (Díaz et al., 2004).

Table. 3.4 Flowchart process for extraction of banana/plantain fiber

Process: Platain fiber by an extracting machine.				
Material:	**Activity**	**Actual**	**Time: 1:** 30 Seg **. 2:** 601.5min	
Date:	Operation ○	14	**Cost:**	
Operator:	Transport ⇨	2		
Comment: time for 30 Kg/hour	Delay D	1		
	Inspection □			
	Storage ▽			

Description of activity	Symbol					Time (Sec.)	Observation:
	○	⇨	D	□	▽		
1. Pick up	●					1	Pseudostem sheaths
2. Introduce	●					2	In the extracting machine
3. Hold up	●					7	The pseudostem sheaths.
4. Extract	●					7	The pseudostem sheaths must be rotated to continue with extraction.
5. Twirl	●					3	To the other side
6. Introduce	●					3	For finished completely.
7. Hold up	●					3	Pseudostem sheaths
8. Extract	●					3	Pseudostem sheaths from the machine
9. Hang	●					1	Continue with other Pseudostem sheaths.
10. Collect	●						Residue.
11. Transport		●				1(min)	To soaking area.
12. Soak	●					600(min)	Allow to soak overnight, to remove waste.
13. Transport		●				2 (min)	To drying place.
14. Hang	●					1(min)	On a rope, outdoors.
15. Wait			●			18(hr)	About a day until dry.
16. Comb	●					15 (min)	Combing while soaking.
17. Collect	●					1 (min)	Residue.

Source: (Rodríguez & Suarez, 2010)

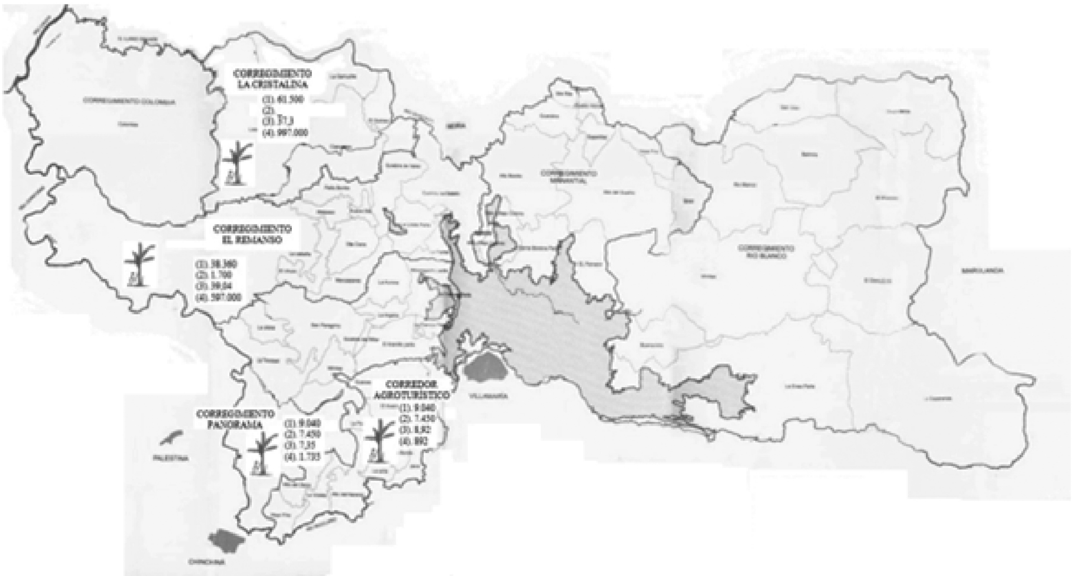
For fiber extraction, pseudo-stem is cut at 5 cm height from soil level andthen is transported to a collection area where is separated into pseudo-stem sheaths (see Fig 3.3b). The fiber is extracted by means of manual, mechanical or chemical procedures. When using manual removal one person production rate is 1kg/h (or 1 hour 40 min by plant). This procedure can be considered for the production of small amounts of fiber(Rodríguez & Suarez, 2010). In general the process has four main steps: extraction of the fiber, washing (24 hours), air drying and combing (Table 3.4).

Table 3.4 describes fiber machine/mechanical extraction by manual feeding. Estimated production rate is 30 kg/h and requires 11 operations. The cost of the extracting machine is around US$ 4100, which is a high cost for banana-plantain farmers. It is therefore recommended to place these equipments in each of the fiber stocking centers located strategically in the four producer corregimientos. So, farmers would transport their complete pseudo-stem or sheaths to the nearest fiber stocking center, for fiber treatment and or extraction. Alternatively, it coul be used another high volume machine for doing this procedure called mechanic decorticator. This option is reported to guarantee an operational cost of US$ 0.89/kg extracted fiber (Satyanarayana et al., 2007).

BANANA-PLANTAIN FIBER POTENCIAL IN MANIZALES MUNICIPALITY

The administrative divisions in Colombia include Departaments (states), Regions, Corregimientos and Veredas. Departaments are divided into regions which in turn have municipalities. Rural areas of a municipality are divided in veredas and corregimientos (a group of veredas). The word "vereda" in spanish has the same meaning that road in where, at some time and some points, were established families and built a hamlet or village, dense or sparse. In Manizales municipality (Caldas departament capital) banana and plantain are produced in four corregimientos: La cristalina, El remanso, Panorama y Corredor agroturístico.

Figure 3.5. Geographic location of Banana-plantain cultivars in Manizales municipality



Plantain planted plants (2) Banana planted plants (3) Hectare (4) Production kg/year

Figure 3.5 shows their location into the map of Manizales together with the number of plants and hectares of banana/plantain planted and their annual production (data provided by the rural development area of the municipality of Manizales in 2009).

Table 3.5 shows the estimated potential of banana-plantain fiber production by corregimiento and in the municipality. Manizales rural area has then a potential of 209 tonnes/year. In contrast, Caldas department has an annual fique production of 204 tonnes (Table 3.2).

Table 3.5 Manizales municipality and corregimiento's estimated production of Banana-plantain fiber

CORREGIMIENTO	PLANTED PLANTS		HECTARE	PRODUCTION Kg/year	FIBER PRODUCTION POTENTIAL Kg
	PLANTAIN	BANANA			
La Cristalina	61,500		37.3	997,000	103,781
El Remanso	38,360	1,700	39.04	597,000	67,601
Panorama	9,040	7,450	7.35	1,735	27,836
Corredor Agroturístico	1,480	4,510	8.92	1,209	10,108
TOTAL					209,326

Dried pseudostem fiber per plant ca. 1.69 Kg

FARMER EXTRA INCOME ASSESSMENT

In this section it is estimated the additional income associated to the potential banana-plantain fiber exploitation and commercialization in Manizales municipality. For selling price calculations there were analyzed two different scenarios: the first one considered the commercialization fiber price for manufacture of artisan stuff. The second option considered a similar market fiber price for industrial fiber manufacturers in Colombia. Currently, Caicedonia (Valle) artisans are offering raw banana-plantain fibre at US$ 8.22/Kg while industrial use fique is traded at US$0.82/Kg (top quality) and US$ 0.68/Kg (regular) respectively.

For estimation of volume value trade of banana-plantain produced in Manizales, the price of plantain fruit ranges between US$ 0.25 and US$ 0.38 per unit depending on its quality (data reported at the marketplace of the city of Manizales).. A plantain bunch has between 40 and 60 bananas. Therefore 50 plantains by US$0.32 is equals US$ 15.77/plantain bunch.

All aforementioned prices corresponded to information collected in March 2013. To give an idea about price stability, in Corabastos marketplace (Bogotá) the plantain fruit price dropped 3.69% in 2012 (Corabastos). For both, plantain and fiber there were considered post harvest losses of 10% of total produced volume.

From the information included in table 3.6 volume value trade of fruit and fiber are similar when considering fiber selling price in scenario 1 (valued at approximately US$ 1.5 million). If the fiber would be commercialized with fiber industries exclusively, the fiber volume trade would account between 7.28% and 8.77% volume value trade of banana-plantain fruits.

Table 3.6 Cost approach from the sale of banana and fiber.

	Fruit volume value trade*		Fiber volume value trade*			
CORREGIMIENTO	**Plantain planted plants**	**US$**	**Kg of fiber**	**Scenario 1, US$**	**Scenario 2,**	**US$**
La Cristalina	61500	872,869	103781	767,771	76,590	63,513
El Remanso	38360	544,443	64733	478,894	47,772	39,616
Panorama	9040	128,304	15255	112,856	11,258	9,336
Corredor Agroturístico	1480	21,005	2498	18,480	1,843	1,528
TOTAL	**110380**	**1566,623**	**186266**	**1378,003**	**137,465**	**113,995**

* Post harvest losses of 10% included.

Scenario 1: Fiber selling price: US$ 8.22/Kg. Scenario 2: Fiber selling price: US$0.82/Kg (top quality) and US$ 0.68/Kg (regular)

As described above in the survey research, most of the banana-plantain rural growers are small farmers that depend largely on fruit trade. Considering an average cultivated area of 0.05 hectares, 50 plants/Ha, table 3.7 shows the estimated annual income/farmer, considering 10% post-harvesting losses. In scenario 1 sales of fiber would exceed the fruit ones. This is an ideal situation because only a few part of fiber production could be sold to artisans. However, if the fiber would be better to consume at similar prices of top quality and regular fique fiber, farmers would increase, as mentioned above, between 7 and 9 % over their currently annual income.

Table 3.7 Income simplified calculation for a typical little farm with 50 plants of banana-plantain.

Fruit Income		**Fiber Income**	
Bunches	50	**Fiber**	84.38 Kg
Net value	US$710*	**Fiber value (for artisans)**	US$ 624.23*
		Fiber value (for industry):	
		top quality	US$ 62.27*
		regular	US$ 51.64*

*Estimated values with a loss 10%

PROPOSAL FOR FIBER STOCKING CENTER PLACEMENT

In each corregimiento, and based on the vereda's production, there were estimated the fiber stocking center geographical coordinates according to the gravity center methodology by using five iterations. The resulting coordinates were adjusted considering the proximity to a main road. In table 8 is shown the detailed data for the 5Th iteration.

Table 3.8 Fifth iteration sample calculation for fiber stocking centers coordinates by the gravity center method.

LA CRISTALINA					EL REMANSO				
Vereda		**Location**		**Production Quantity**	**Vereda**		**Location**		**Production Quantity**
		x	y	(Kg)			x	y	(Kg)
El Guineo	1	7.20	3.09	2278		1	3.92	4.53	18225
Lisboa	2	2.52	4.51	30375	**La Cabaña**	2	6.10	4.82	3796
La Arabia	3	3.84	5.65	60750		3	8.34	4.39	1518
					El Chuzo	4	10.30	5.61	16341
					Santa Clara	5	12.02	4.21	2733
					Vélez	6	13.03	2.42	18225
X* Y*		**8.35**	**12.29**		**X* Y***		**9.91**	**4.86**	
PANORAMA					**CORREDOR AGROTURÍSTICO**				
		x	y	(Kg)			x	y	(Kg)
El Rosario	1	2.03	6.98	4556	**El Aventino**	1	4.81	2.74	6364
La Aurora	2	6.32	1.35	14246	**Bajo Tablazo**	2	5.51	3.31	2202
Los Días	3	4.09	2.70	5756					
X* Y*		**5.89**	**1.71**		**X* Y***		**4.81**	**2.74**	

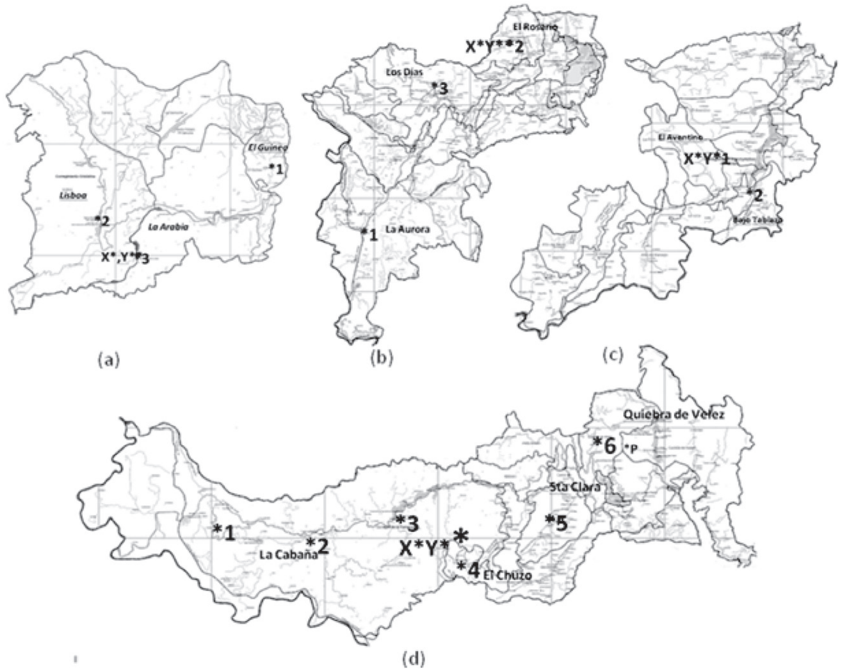
Coordinates in Km.

Fiber stocking centers are required for technical exploitation of fiber because low income farmers have not economic capacity for establish their own extraction facilities. The logistic arrangement suggested here is also necessary for quick transportation of raw material, avoiding the fast microorganism accelerated decomposition of high moisture pseudo-stems. Ideally, fiber stocking center services must include manual feeding extraction and spinning machines for increasing the commercial value of the fiber.

According to the results the recommended locations of the fiber stocking centers are:
Corregimiento La Cristalina: Location point in the higher banana-plantain producer vereda La Arabia (65.04% of corregimiento's production). Lisboa and El Guineo veredas are interconnected by municipal road. The linear distance to the suggested fiber stocking center is 1.78 km and 4.77 km respectively (See Fig. 3.6a).

Corregimiento Panorama: Location point in the higher banana-plantain producer vereda La Aurora (58% of corregimiento's production). El Rosario and Los Días, veredas are interconnected by municipal road. The linear distance to the suggested fiber stocking center is 7.84 km and 2.89 km respectively (See Fig.3.6b).

Figure. 3.6 Fiber stocking center locations by corregimiento: (a) La Cristalina, (b) Panorama, (c) Agroturístico y (d) El remanso.



Corregimiento Agroindustrial: Location point in the higher banana-plantain producer vereda El Aventino (74% of corregimiento's production). Bajo Tablazo is interconnected a linear distance of 920 m (Fig.3.6c).

Corregimiento El Remanso: Location point in the higher banana-plantain producer vereda, near to El Chuzo. La Cabaña 1, 2 and 3, Quiebra de Velez and Santa Clara are interconnected by municipal road. The linear distance to the suggested fiber stocking center are 6.61 km, 4.12 km, 1.81 km, 2.43 km and 4.37 km respectively (see Fig.3.6d).

PROPERTIES , USES AND CHEMICAL MODIFICATION

In addition to hand-crafts use for fique, sisal and jute fibers, they have worldwide recognition as valuable materials for the automotive and construction industries (Mohanty et al., 2005). Although natural fibers have wide range of properties in Table 3.9 is shown that plantain fiber from the Manizales region has outstanding mechanical properties. So, this fiber could reasonably be a good resource for the manufacture of a great diversity of materials as geotextiles, interior and exterior of elements in cars, home and office furniture, pots, containers, packaging,pallets, cosmetics, medicine, paper, cardboard, etc. (Müssig, 2010).

Table 3.9 Comparison of mechanical properties of the fibers of the region (Manizales) with other similar fibers.

Fiber	Tensile Strength	Modulus of elasticity	Break Elongation	Reference.
	Pa	MPa	%	
Banana	384-800	20-33,8	2-6	(Annie Paul et al., 2008; Guimarães et al., 2009; Idicula et al., 2005; Jawaid & Abdul Khalil, 2011)
Plantain	586-1223	22.9-63.3	1.6-3.6	(Rodríguez & Suarez, 2010)
Sisal	347-700	15,2-38	2-7	(Alves et al., 2010; Jawaid & Abdul Khalil, 2011; Pacheco-Torgal & Jalali, 2011)
Jute	450-800	10-30	1,1-1,8	(Alves et al., 2010; Jawaid & Abdul Khalil, 2011; Kabir et al., 2011)
E-glass	1800-3500	86	2,8	

Banana-plantain fiber has also been studied as filling of cement composite materials. For that purpose the fiber must have at least 25% less absorption capacity of water than raw natural fiber (Venkateshwaran & Elayaperumal, 2010).
For doing that fiber transformation the authors have developed, at laboratory level, some chemical treatments that resulted in modified fibers with low water affinity for using in composite materials.

Banana-plantain fibers (BPF) were treated with anhydride acetic (AA), epichlorohydin (EP) and anhydride acetic-epichlorohydin blend (AA_EP). Reagents were dissolved in acetone (weight ratio, 1:10) and raw fibers were immersed in the solution during 24 h at 20°C. Treated and untreated BPF were characterized by, water sorption isotherms, water swelling and chemical resistance to alkali, acid environments and mechanical performance, scanning electron microscopy and Raman spectroscopy.

Weight reduction as a measure of chemical resistance in alkali and acid aqueous solution was studied for BPF fibers. In general, all chemical treatments improved the acid chemical and alkali resistance of fibers.

Figure 3.7 is the average representative stress strain curve of BPF samples. Comparing the mechanical properties of raw fibers with the treated ones and considering errors in the determination of these parameters it looks as if that the chemical treatments used marginally reduce the stiffness of fibers. The mechanical properties of raw and chemically treated BPF were investigated by single fiber tensile tests. However, from the comparison of related published works, even the weaker of the treated fibers in this work showed better or comparable mechanical characteristics than BPF treated fibers extracted from other varieties of these plants.

Figure 3.8a to 3.8d showed the longitudinal sections. Morphology structure changed after all chemical treatments. The untreated BPF Fig. 3.8a is found impurities due to wax and oils substances. With AA, EP and AA_EP treatment the BPF present a smoother surface due to removal some impurities. The change in the surface also could be evidence of removed lignin, hemicelluloses with rupture of cellulose, because the structure began to show a partial defibrillization and damage clearly corroborate by AA and AA_EP Raman spectra.

Figure 3.7 Average tensile stress of treated and untreated BPF

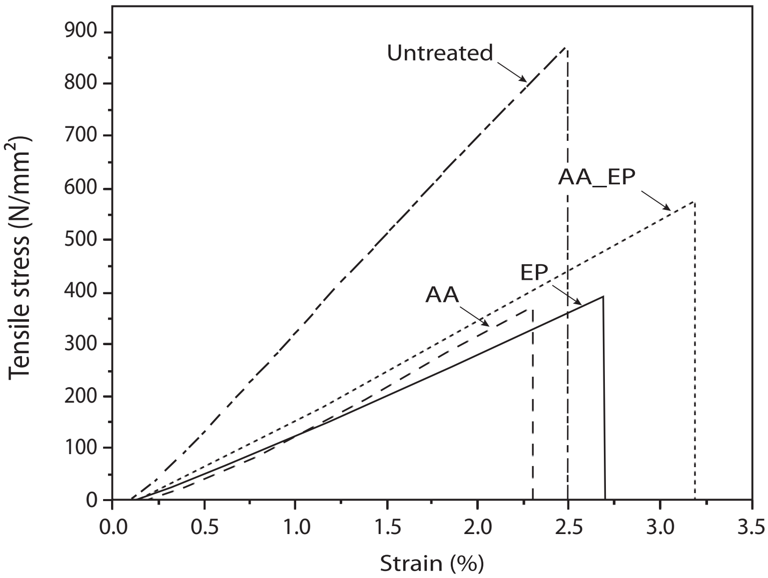


Figure 3.8 SEM for surface at 5000 Figure 3.8 SEM for surface at 5000 X magnification of a) untreated, b) AA, c) AA, EP c) and d) AA_EP. And for cross section at 1000 X magnification of e) untreated, f) AA, g) EP and h) AA_EP.

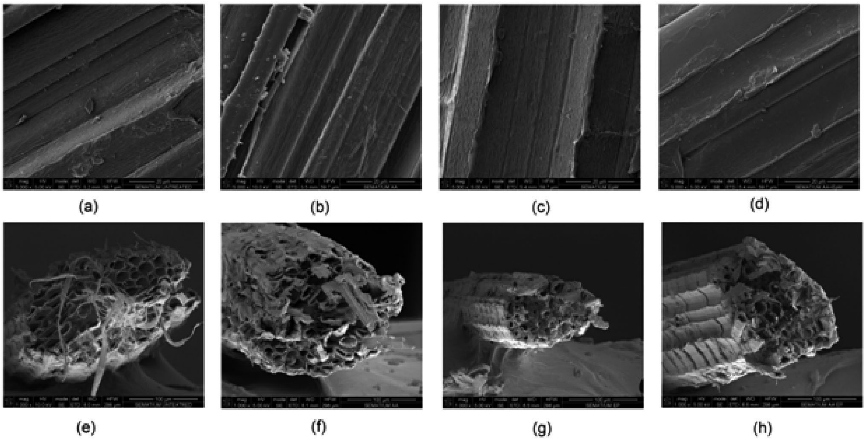


Figure 3.8e to 3.8h shows the cross section areas of the fibers after tensile test. All the micrographies exhibit a structure of bundles of individual hollow strands (microfibrils). This is a general configuration of all natural fibers where bundle of cells are linked by cementing material (lignin and hemicelluloses) and the hollow cavity called lumen (Vilay et al., 2008).

The microfibrils of untreated fiber presents a uniform cutting, in contrast to treated fibers, where showed an irregular notch. This could be evidence of the remotion of cementitious materials that joined the microfibrils. Another interesting effect of chemical treatments was the swelling effect on cross sectional area that was transformed from flat to oval shape as can be observed from the comparison of figures 3.8f, g, h and Figure 3.8e.

Raman spectroscopy show treated fibers reduced their content in hemicellulose and lignin (mainly at 890 and 1600 cm-1 respectively) with also some cellulose degradation (1085-1096 cm-1 band), especially in AA BPF and there were found evidence of new chemical bonds (ester carbonyl -1260 and 1715 and carbon-hydrogen-1330, 1380 and 2900 cm-1) that confirmed the replacement of part of the hydroxyl groups. Same results were showed from the sorption isotherm and swelling in water assays in which the moisture sorption or liquid water absorption of the Banana Plantain Fibers (BPF) was significantly reduced by chemical modifications giving them probably better characteristics for their use in manufacture of composites.

CONCLUSIONS

The importance of natural fibers has been documented since ancient times. Today they can help to find new and sustainable solutions as reinforcement or fillers in composite materials, but limitations such as their heterogeneity and hydrophillicity have not permitted them from entirely replacing synthetic fibers. While the world fiber market is still dominated by synthetic fibers, cellulosics (mainly cotton and jute) are the most important among natural fibers. Fique is the more emblematic natural fiber in Colombia. However, there is an unexploited great resource for these raw materials in the country: Banana-Plantain pseudo-stem-fiber (BPF).

Banana and plantain are important crops in the world and are the foremost exported fruits in Colombia. Globally and locally most of their high volume harvest residual materials are disposed or left on the cultivated area. The Banana and plantain sector provides an important contribution to both economic and environmental development of the country, and, particularly, in its central western region in which they are cultivated as complimentary or alternative crops with coffee.

As a response to the increasing need for assimilating environmentally sound alternatives into supply-chain management research, in this chapter there were first described the economic context in which national and regional potential BPF production are placed in the currently world of synthetic and natural fibers. In contrast with the forward logistics production steps described for other natural fibers (cotton, jute, sisal and fique) it was projected a green recovery scheme for the management of the profuse pseudo-stem residues focused in the rural area of Manizales municipality. A survey with banana-plantain growers was used to estimate the raw material availability, and according to the gravity center methodology, it was proposed the placement of fiber stocking centers for each of the four production corregimientos in which the rural zone of Manizales has banana-plantain cultivated areas. The potential extraction and commercialization of BPF would allow increasing the grower's revenues from 10 to 100% over the actual baseline incomes.

Finally, and taking account the water affinity associated limitations of BPF, there were described some results of chemical modifications of banana-plantain fiber developed by the authors with the final aim of enlarge the future market options of these important and unexploited fiber.

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CHAPTER 4

USE OF AGROINDUSTRIAL BYPRODUCTS AS A RAW MATERIAL FOR BUILDING INDUSTRY

Ricardo Augusto Tolosa Correa
Carlos Ariel Cardona Alzate
Oscar Hernán Giraldo Osorio
Nayda Patricia Arias Duque
Juan Felipe Palacio Rivera

Universidad Nacional de Colombia sede Manizales

INTRODUCTION

Plants contribute in an important way to food sustainability; production of medicaments, oils, biofuels, and textiles, Cardona et al., (2010). Furthermore, they serve as fibers in both artisanal and composite applications for different usages, ACI (2001). In this latter application, plants that provide cellulosic fibers have picked up gradually their lost value due the appearance of petrochemistry, Tolosa et al., (2008).

Moreover, it must be considered that once the plant has been used, a number of residues are generated, which although mostly are biodegradable, they cause contamination and produce harmful effects to the environment. Furthermore the agroindustrial production maximizes the plant productivity, but at the same time it generates a larger amount of residues, that emphasize the problem when they are disposed in an uncontrolled manner. That is why the reduction of waste, the increase of reuse, recycling and use of alternative innocuous materials to the environment, results in maximizing the efficient use of resources , CCE (2003).

In this context, not only it must be think which usages give to the plant, but also to the residues, especially when they are produced in large volumes. Residual biomass of the agroindustrial process is a highly polluting source, due its degradation contributes the output of greenhouse gases, pollution of air, in the case of being disposed to open sky, it occupies lands agriculturally active, and when it is deposited in landfills, it degrades the soil as well as the hydric sources, Tolosa, (2005); Karade, (2010). In this line of thoughts, generate proposals that allow its use, implementation, and insertion to the productive chain is really attractive, and the utilization of these residues as raw material that conforms a new construction material results a viable alternative.

In consideration after mentioned, this chapter will address the concerned topic, initially outlining the concept useful life of buildings and the infrastructure as articulating elements of the reverse logistics chains. After, it address the aspects related to the science required to the use of residual biomass in form of fiber or ash, as raw material of construction materials, and the conditions which must be confronted when are used, finally, there will be an approximation of applicable biomass in the Colombian case and its possible impact.

It is noted that in the construction materials field, biomass can be part of composites when it is used as fiber or when this fiber is transformed into ashes or aggregates, both of those are important part of reinforced cementitious matrix. This cementitious matrixes can be of polymeric, and ceramics sources or hydraulic cement, cement-cellulosic, cement-polymeric, soils or the natural origin makin important part of biiocomposite. as a reinforce fiber, ashes or aggregates, and the matrixes can be origin of polymeric, ceramic, origin, hydraulic cement, cement-cellulosic, cement-polymeric, soil, or natural origin as biocomposites. Nevertheless, this chapter will focus the use of biomass as fiber or ash, and its inclusion in hydraulic cement matrixes, where are formed aqueous dispersions of low solubility powders coming from mineral oxides based on hydraulic binders, Gartner *et al.*, (2011). The reason is founded on the improvement of the mechanic conditions, rheological and durability of the composite material are remarkable, and because this is the most used matrix in construction of buildings and infrastructure.
It is expected that this chapter be set as a discussion text and decision making, in order to achieve viable solutions

which make possible the use of agroindustrial residual material produced in large volumes for the Colombian context.

USEFUL LIFE CYCLE OF BUILDING AND INFRASTRUCTURE

Useful life is a parameter which establishes the capacity that building and infrastructure must have, in order to support properly the solicitations associated to the use that they are subjected, and the actions that affect their functional capacity; this implies the association the concept of durability.

In itself, the concept of useful life responds to a contemporary criterion applied to reinforced concrete structures, and due its connotation can be extrapolated to the general building. This concept was defined in 1989, by the Comité Euro-International du Béton (CEB), as the time during which the structure maintains a minimum of the performance (security, functionality, and esthetic), for it which was projected, without high costs of repair or maintenance, Pazini et al., (2003).

This conception defines that the building or infrastructure must be conceived, for the case of new constructions, and analyzed, when these already exist, under parameters depending on their performance condition and the time which it is expected that they provide an optimal level of functionality. A simplified model, but quite representative of durability of a structure, it was suggested by Tutti in 1982, and it has suffered some modifications by several authors like Beeby 1983, Andrade 1992, Helene 1993, there it is consider a time-dependent degradation. This model considers the useful life time of service and defines two moments, the first one, is the instant in which the process of corrosion in the structure begins, and the second one is the period of time of its propagation, there useful life ends and begins the residual life, which is the time that is available to perform necessary reparations.

On the other hand, for the estimation of the useful life of reinforced concrete structures, it has been advanced from the traditional concept of structural reliability, and they have generated a series of models, which seek to materialize the degradation of the structure starting from probabilistic schemes like the theory of failure probability, that considers the load at which it is subjected the structure and the resistance of the material, Martinez et al., (2001).

There are also integral methods of design and evaluation of structures, among these are: The deterministic, the stochastic, and the one that considers security factors (ibid). In the deterministic method, the load, the material resistance and the useful life are fixed quantities; in the stochastic these variables are considered functions of probabilistic distribution; now, the security factors method is based on security and reliability following a deterministic process.

Regarding to the buildings and infrastructure, the service life time of constructed objects is much larger than the time allowed for its design and construction, León et al., (2008), this aspect is results significant because largely the uncertainties of design and increasingly shorter construction time, results in a decrease of the service life. Under this consideration, it is clear that the optimal condition of a healthy and durable building healthy building and durable would be represented in counting with enough time to design and reasonable time for construction.

Moreover it is observed that greatly the pathological problems, both construction as infrastructure, are associated to the conception and overall project management, and the not appropriate execution of the constructed element. Furthermore, it turns representative the fact that materials failure represents almost the 20% of the observed damage, Pazini et al., (2003). This unwanted condition is that justifies consider the improvement of the materials will form the reinforced concrete structures. The insertion of fiber and ashes contribute to the increase of the mechanical capacity and durability, so increasing the useful life of the composite, and the constructive element where this is located, also contributing to the generation of materials with relevant performance optics. Its inclusion becomes relevant because allows the valuation of agroindustrial residues, and the generation of new possibilities of use.

NATURAL FIBERS FEATURES FOR THEIR EMPLOYMENT AS REINFORCING RAW MATERIAL OF HYDRAULIC CEMENT MATRIXES

When fiber expression is used, it refers to the particles of which the cross section is less than 0.05 mm2, its diameter is lower than 250 µm, and its length/diameter ratio more than 10, however, fibers with diameters up to 1 mm, and varying lengths up to 75 mm, are applied in construction systems, ACI, (2001), nevertheless, fibers present a better tensional behavior as their diameter is smaller.

Equally, the fiber is classified according to its hardness, it can be hard, if it comes from leaves, Castellanos, et al. (2009), or soft if it comes from the stem (ibid),

When is considering the reason why the study of natural fibers takes validity, is worth noting they become valuable when it is talking about to sustainability, renewable raw materials, biodegradability, and recyclability. In the past was questioned their use due the characteristics variability, which depend on the type of plant, growth conditions, weather, and postharvest handling. Nonetheless, according to the results reported by ACI (ibid), for their implementation as reinforcements in various matrixes, the composites showed relevant parameters such as tensile strength, compression, fatigue, fracture, increased modulus of elasticity, where these are noted for their contribution to the mechanical improvement. Also, the reinforcement increase the capacity against external actions (Control cracking, impact resistance, abrasion resistance, thermal expansion and contraction) (Ibid.).

For their use it has been established microstructural aspects, like the fiber orientation according to the loads direction, contributing to achieve better rigidity and strength of the composite material. Nonetheless, the lack of uniformity remains as a palpable problem; characteristics like chemical composition, crystallinity, surface properties, diameter, cross section shape, length, strength, and rigidity, determine different behaviors, affecting directly the composite reproducibility and the production of this material to industrial level, where it is seek for high levels of standardization, Lilholt et al., (2010).

Nowadays fibers of natural sources are a fundamental raw material in the composite formulation and within a matrix can come to achieve a primary or secondary role of reinforcement, giving them the faculty of versatile use which configures them as essential in the production of new composite materials.

DURABILITY OF COMPOSITE MATERIALS REINFORCED WITH NATURAL FIBERS

When it is pretended to generate composite materials in which the natural fibers are used, the crucial aspect of their performance is associated to the interfacial adhesion between fiber and matrix, this depends on the compatibility between them, which is seriously affected when the matrix is hydrophobic while the natural fibers are of hydrophilic character, Leão *et al.*, (2011), moreover, by their hygroscopic capacity they present a low level of adhesion to the matrix, ACI, (2001). Other aspects which should be consider are the fiber degradation by the microbial and microorganisms action, the chemical attack that it may suffer due to the chemical nature of the matrix, which results in complex parameters to control when it is mixed with hydraulic cement matrixes due to its alkaline nature that provide an accelerated fiber degradation. The other aspect to considerate is that the fiber has low capacity to support high temperautres, attribute that would be leave entirely to the matrix (Ibid.).
Under this context the natural fiber has a limited application, which is why it must be seek treatments that modify the surface, giving the proper protection in the local environment after mentioned, implying an additional cost, Faruk *et al.,* (2012); Bledzki *et al.*, (1999) In this way, the literature report several techniques to improve the fiber properties, among them:

Physical treatments: Their aim is the modification of the structural and superficial properties, but without affecting the fibers chemical composition, achieving a better mechanic union in the fiber-matrix interface. For example, electric discharges (Corona discharge) activated the oxidation of the surface and modified the surface energy (ibid).The use of plasma, can achieve similar results, Kalia et al, (2009), furthermore, depending on the type of gas used, it can achieve different kind of modifications such us creations of free radicals and reactive groups on the fiber surface (Ibid). There are other physical treatments that can be use as stretching, different thermal treatments techniques and hybrid yarns, Faruk et al., (2012; Thomsena *et al.*, (2006).

Chemical treatments: Their aim is make compatible the fiber with the matrix, modifying chemically its surface and in some cases introducing third specie with intermediate properties which works as a bridge for the interfacial bonding between the fiber and the matrix. The following treatments can be found:

Alkali treatment (mercerization): This treatment removes elements like lignin, wax, and oils, from the external surface of the cell wall. Other effect is the increase of fiber roughness due to the breakdown of hydrogen bonds of the network structure. One of the most commonly employed solutions is to use sodium hydroxide. Van de Weyenberg et al., (2006); Sgriccia et al., (2008); Mohd et al., (2007); Geethamma et al., (1998); Ghali et al., (2009); Gomes et al., (2007); Geethamma et al., (2005); John et al., (2008).
Acetylation: Which the main objective is to cover the fiber surface with OH groups that are that are responsible of the hydrophilic characteristics of the fiber, Bessadok et al., (2007); De Rosa et al., (2011); Sreekala et al., (2003).

Further the mentioned treatments, there are others like: impregnation of fibers, a technique that is commonly done with lime and paraffin, coupling, exposure to ultraviolet radiation, Rahman et al., (2007), compounds containing styrenes, Bessadok et al., (2008), diisocyanates treatment, Geethamma et al., (2005); Sreekala et al., (2003); George et al., (2012), with benzoyl chloride, Paul at al., (2008) and with potassium permanganate in organic solvent (Ibid.); George et al., (2012;) Merlini et al., (2011).

As it can be seen, there are many possibilities of treatment, each one of them applicable to a particular demand and the expected behavior which to have the composite when the fiber comes in contact with the matrix. What is sought is that the fiber interacts with the matrix such it does not degrade, remains stable and achieve an optimal level of interfacial bonding, finally the chemical and physical treatments intended that the composite improve its durability reaching a competitive performance, increasing its durability. Other aspect is evaluating the cost which must be analyzed to industrial scale, aspect that probably will limit the choice of treatment.

CEMENT MATRIXES REINCFORCED WITH FIBERS

When contemplating the use of fibers as reinforcement element in hydraulic cement based matrixes, the alkalinity of the matrix becomes a significant obstacle because this condition speeds the fiber degradation Beraldo, (2011); Agopyan et al., (2005), that what is essentially due to the alkaline hydrolysis of the cellulose molecules causes the chains degradation, and also because it presents the dissolution of lignin and cellulose which breaks the bonds to cellular level.

Another aspect to consider is the dosage of composite matrix and fiber, which results more complex in untreated fibers inasmuch as the present glucose on the fiber acts like a retardant, influencing the mix of concrete or mortar. ACI, (2001).

The employment of natural fiber within the hydraulic cement matrix seeks to establish a bridge effect that absorbs tensional stresses to which the matrix is subjected, this effect is known as “bridging” , Marshall et al., (1985); Budiansky et al., (1986), and is tested in young concretes that are susceptible to hydraulic shrinkage, rapid evaporation of surface water exuded, and hydration heat. Regarding to the first action, this is presented by the reduction of volume that the concrete experiences once it has hardened, and is due to the matrix change of status, passing from an elastoplastic condition to a hardened state; in this process occurs consumption or exudation of the water of the mix, generating tensions within the matrix, and unless they are given the appropriate treatment will result in cracking that lead to reduction of the element useful life.

The second action is presented when the cured is not enough or when the weather in which the constructive element foundation becomes a relevant that promotes desiccation of the surface. This condition occurs mostly in dry climates, low relative humidity or low rain regime, or places where the wind action is such that dries out the outside.

Under the previous conditions is manifested a phenomenon known as plastic shrinkage, it is generated by a stress difference at superficial level which affect the material significantly. Concrete has high capacity to withstand compressive stress but is weak when it is subjected to traction, which occurs precisely when water evaporates.

The third action, is itself an innate characteristic matrixes of hydraulic cement or cellulosic cement, it is presented in early life and is consequence of the exothermic behavior of the chemical reaction, when starting the process of hydration of tricalcium silicate (C_3S) and tricalcium aluminate (C_3A), cement components. This increase is enhanced as the cement or the addition employed to generate the composite material, achieves a greater surface area, resulting in a finer grain size.

Now, with regard to the use of fiber as reinforcements of this kind of matrixes, other aspects must be consider: The quantity of fibers included in the matrix, which rarely exceeds 5% of the total volume, or in a amount of weight that is between 2% and 12%, which is very variable as reported by various authors, Morh et al., (2004). The reason is because the concrete also contains coarse and fine aggregates which do not allow the introduction of fibers to great scale, this is due the concrete production technique itself, which results in a fiber clustering, that should be avoided, and that occurs most commonly if are used long fibers or in a large proportion. Additionally the workability of the composite material is compromised; this is due the increasing of the surface area and water absorption, in the case of untreated natural fibers with coatings that inhibit this condition.

Moreover, if the concrete presents cracking by internal or external actions, it facilitates the penetration of water and other agents, leading to an endless number of pathologies that eventually end in corrosion of reinforcing steel, which decreases the durability and useful life cycle of the material.

At the same time this water inlet affects the fibers, and together with the concrete alkaline environment, becomes a triggering factor weakening the constructive element and speeding its degradation process, therefore is important the employment of treatments to protect the fibers, and also the use of additions to help mitigating the problem, Pacheco et al., (2011); Coutts, (2005); Savastano et al., (2002); Juárez et al., (2007).

ASHES FEATURES FOR THEIR USE AS ACTIVE ADDITIONS IN HYDRAULIC CEMENT MATRIXES

The use of ashes of some vegetable biomasses as raw material to the generation of new construction materials or the improvement of the existing ones, has extended over the world, due its use mitigates the environmental damage which is caused by the own biomass or the ashes itself when these are disposed improperly, and because they improves the mechanical properties especially the compressive strength and durability of cement matrix.

The biomass calcination offers as added value the generation of energy, furthermore, this process can achieve the considerate reduction of biomass volume, and if the technique applied to generate energy is suitable, the resulting ash will have space as feedstock for the production of materials in the construction sector, Tolosa et al., (2008).

The combustion generates two types of ashes, flying and bottom boiler It is worth to indicate that the ASTM C-618 framed the fly ash as the one coming from coal combustion, and only making clear what is consider as fly ash does not include residues of incineration of municipal or industrial waste, ASTM C618-08a, furthermore, it does not consider other biomasses. This is why; this definition has been revalued by several authors on the understanding that the fine-grained ash or fly ash, is not necessarily exclusive of coal calcination, Vilches et al., (2005); Maschio et al., (2011), and this type of ash is produced by different types of biomass, therefore the denomination given to the term should be more extensive.

On the other hand, is has been talking about the term "addition", which applies to pozzolanic materials that are used as raw material aggregated to the matrix, with the aim to improve it. A pozzolan, as it is defined by the ASTM-618, is a siliceous material or alumino-siliceous that by itself possesses little or no cementitious value, but when it is finely divided and in the presence of water, it chemically reacts with calcium hydroxide at room temperature forming compounds with cementitious properties, Aguila et al., (2008). Similarly, an addition may be active if it has pozzolanic capacity, if it has not, in which case it acts as filler within the matrix.

Meanwhile, for an ash to be highly reactive it is required that the biomass be transformed and optimized in a proper manner with the aim to accomplish an activating function within the matrix, connotation allows it to act as an addition. It should have the following characteristics:

1. The amounts of SiO_2, Al_2O_3, and Fe_2O_3 should be exceeding the 60% of the total oxides. Furthermore, the ternary diagram silica (SiO_2) - alumina (Al_2O_3) - iron oxide (Fe_2O_3), allows placing the addition on the basis of content of these compounds and providing the pozzolanic aptitude to the ash must have. In addition it is worth to highlight that the ash is more attractive if the silica content is higher, Vassilev et al., (2013).

2. High specific surface area, it is to say very high fineness, and the grain size could be below to the cement grain size. This parameter has turned the fly ash to be more active than the boiler bottom ash. It is also very important that the ash has a uniform size particle distribution, Vassilev et al., (2013).

3. Limited quantities of some oxides, which can affect the final material by phenomenon associated to expansion, alkali-aggregate reaction, resistance against sulfates and chlorides. Among these are SO_3, MgO, K_2O, and Na_2O, Taylor, (1997).

   In some cases these oxides are present in considerable quantities in the ash resulting from the vegetal biomass calcination, which generally can be attribute to soil condition where the biomass comes from, such example is the case of oil palm, for which some studies report significant amounts of K_2O, nevertheless when analyzing the durability with its inclusion in hydraulic cement matrixes a significant affectation is not reported, Chindaprasirt et al., (2008); Tangchirapat et al., (2007).

4. Limited ignition losses or low quantity of unburned carbon. Again, the fly ash results being more suitable

than boiler bottom ash, this is essentially due the ignition losses of the boiler bottom ash is higher, and the unburned produced modified the adherence of the paste to the aggregates and decreases the durability of the material.

Possessing an amorphous structure, which can be achieve if the calcinated material is not allow to rearrange the crystal structure, avoiding the formation of crystalline forms of some oxides associated to the ashes, Schaffer et al., (2000). Likewise, in the case of plant biomass, the amorphous structure is obtained when the combustion temperature is kept between 400º C and 800º C, Martinera-Hernandez et al., (2000).

In this way, studies done by Mejia et al (2007) over rice husk ashes employed as addition of concretes, showed that for initial ages it is more representative the sizes grain effect than the own amorphicity, because finely sizes contribute more forcefully to the achievement of higher strengths at early ages, an interesting consideration because it is expected that a low grade of crystallinity should be the one who manage the dynamic reaction of the composite material at early ages, in this sense and as it is outlined by Tobón et. al. a finely addition speeds the cement hydration process and the formation of hydrated calcium silicates, which can helps to rapidly increase the gain of compression strength, Shih et al., (2006). Worth underlining that this behavior was studied in silica fume nanoadditions and reported by several authors, Shih et al., (2006); Li et al., (2004); Li, (2004), who agree on the high nanoadditions pozzolanity, but diverge at the time when this promotes the resistance gain, as in the optimum amount that should be employed when is included as part of a composite material based on hydraulic cement matrix.

On the other hand, a really small grain size as is true helps to seal pores of the composite material, with no doubting contributes to its durability improvement, and promotes the cement reaction; it also presents an inconvenient issue, and is the decrease of workability of the material, which would require the use of additives superplasticizers, and eventually water, Li et al., (2006), implications that should be studied with regard to analyze how to adjust the work formula, how it would be the interactions with other feedstock and its effect over the composite properties and how it is affected the material cost.

Another factor that should be considered is the hydration heat increase and its relation to the grain size, Tobón et al., (2007). Moreover, several authors contemplate that the hydration heat is directly related to the composite pozzolanic activity, Li, (2004), nonetheless, an elevated hydration heat favors the appearance of cracking in it, Li et al., (2006), which results undesirable because not only affects the quality of the constructed element from the esthetics, but the existence of cracking or microcracking compromises the composite material mechanical capacity, decreasing, as was already set, the durability and the useful life cycle.

It also happens to be a differentiating aspect, the calcination technique, which must be done in a controlled form with the aim to eliminate almost entirely the organic fraction, with temperatures that are above 650 °C, Tangchirapat et al., (2009); Cordeiro et al., (2005). In this regard Hwang and Chandra describe clearly the effect of temperature, calcination technique, and its own effect in the husk rice biomass, Chandra, (2002). It should be also considered as a factor that influence the quality of the ash, the residence time in the furnace hearth and its fast or slow cooling.

BIOMASS COLOMBIAN CASE

To address this part of the chapter it will be deal with the matter from a macroeconomic perspective, then, and from the agricultural production, address the products which support the proposal for biomass to be used as raw material for the generation of construction materials based on fibers and ashes.

Colombia during the period 2000-2011 has maintained an economic growth rate that has resulted positive, World Bank, (2012), even on world economic depression years like 2009 which presented a low but positive growth. Furthermore, is noteworthy that the years in which observed significant declines of the Gross Domestic Product (GDP) are associated to political circumstances that have affected and decreased the investment.

In this same period of time it has been seen as the agriculture, economic sector which brings together hunting, fishing, forestry, animal breeding and crops, has decreased its participation constantly on the GDP, loosing almost 2 points. The sector participation on 2011 was the 6.8% of the GDP (ibid.), nonetheless and despite the participation loss in the GDP, and exception of years 2008 and 2009, where it presented negative growth, agriculture has presented a positive growth, Ministry of Agriculture and Economic Development, (2012), which is really variable, what can be attribute specially to climatic aspects, internal economic conditions, conditions of sale in international market, etc.

On the other hand, in 2011 for agricultural production, Colombia used slightly less than 37.603.500 hectares, of them, only the 7.75% were used in agricultural activities, livestock activities employed the 77.5% of the total, DANE, (2012), which denotes that the livestock vocation is quite high, aspect that affects the soil by erosion and loss of topsoil. Equally it should be considered that the 59% of agricultural activities are intend for permanent crops, just under 1.2 million hectares, the remaining 39% is dedicated to seasonal crops and set-aside, and 3% to fallow lands (Ibid). It is evident that the amount of cultivated land in the country is quite low.

Another interesting aspect is the one related to the rural population, draws attention that unlike a lot of developed countries, Colombia has slight but constant growth of rural population, which during the period 2000-2011 increased by just under 500.000 inhabitants. Nevertheless, the rate of population growth has been decreasing compared to urban population in almost 3%, for year 2000 was located in the order of 28% and for 2011 was 25%, World Bank, (2012). This tendency is interesting because despite of existing in Colombia displacement phenomenon of rural population, it continues growing and could indicate that fluctuation occurs between the urban and rural population. It should be noted that the growth of the urban population is a constant in almost every country of the world, nonetheless, in general there is a relation almost constant between growth and decline, this is why the Colombian case results interesting and allows setting out from now that reverse logistic chain based on materials generation from agroindustrial residual biomass is viable.

This posture is more representative when looking the jobs generated by agriculture regard to the entire jobs of country, presented a decrease of just over 4%, from 22% in 2001 to just 17.9% in 2011 (Ibid). This negative variation contrasted with the population growth justifies the analysis of the use of biomass viability to generate construction material industry; this would allow the creation of new jobs.

Now, in regard with the construction sector, it can be indicated that its contribution to GDP was near 5.2% in 2002, increasing to 5.9% in 2011. Although pointing out that in the 2002 – 2011 period, the GDP of construction grew in 71%, DANE, (2012), which proves the sector dynamics. It also can be observed that in general the country tendency is that in periods of increased housing construction declines the investment in civil constructions and vice versa. This behavior is altered in few time periods and draws attention because for the country achieve development, requires constant investment in both infrastructure and housing.

Equally, while observing the cement production in the country it is observed that in 2000 were produced 1.8 million tons, and in 2011 was of 2.255 million tons, presenting an upper limit in 2008 when reached the 3 million tons. The growth is quite interesting; especially when biomass in the form of ash could be feedstock for cements and concretes production, increasing, as previously mentioned, the useful life, durability, and performance capacity of composite materials, contributing to environmental sustainability by mitigating waste, which is evident, reduction of cost production of cements and concretes, and creating jobs in rural areas.

BIOMASS AS FIBER OR ASH

In order to establish the biomass which is susceptible to be proposed as possible feedstock for construction materials that are viable to successfully be introduced into hydraulic cement matrices, it will be make a selection of them according to the following criteria:

1. Agricultural or agroindustrial production. It is required that the residual biomass resulting from the agricultural or agroindustrial process, be of high production, the reason is because to consider the generation of construction materials to industrial scale significant quantities of it are required. Furthermore, it must be with crops that can be found in a same region, due the reduction of logistic cost.
2. Optimal biomasses. For the case of fiber production is necessary to count with crops with low ratios between the fiber extraction cost and the quantity of fiber obtained in the process, in addition to possessing crops in which can be obtained fiber as uniform as possible with good tensile strength and appreciable length . With regard to ashes, it must be established the content of silica, alumina, and iron oxide, in order to evaluate their potential.
3. Referents. Through the exposed in literature, it is determined the experiences in the national or international

context which help to establish some biomasses that have been employed with relative success for proposed aims, as those less studied but can potentially be useful to achieve the proposed goals.

Analyzed the previous criteria, are chosen to move forward the proposal of biomass application, in the case of fiber, the rachis and pseudostem of plantain and banana, pineapple leaf, oil palm residues after its extraction, sugarcane bagasse, and jaggery cane bagasse; the latter two are included as a demonstrative manner because their main use are the ashes due to a high percentage of this biomass is employed to energy obtaining in the sugar factory and oil palm production plant. For the obtaining of ash is proposed the employment of rice husk, mesocarp of oil palm, jaggery cane bagasse, and sugarcane bagasse.

Is worth noting that Colombia in 2004 appeared as the first worldwide sisal producer, MADR, et. al. (2004), and in 2005 the tenth worldwide fiber producer thanks to this product, MADR, (2006), and in spite of sisal having a relevant level of commercialization and use in the country and the world, this plant is not considered in this proposal, because in this document are considered those agroindustrial products with prospects of use in the context of reverse logistics. And the understanding this concept as part of the management of the supply chain that is responsible of recovery operations, recycling and devolution of materials with aim to generate products with high added value, reducing the environmental impacts caused by them.

The reason why sisal is not considered inside the suggested proposal, lies in the fact that this fiber is exploited in Colombia as the main product of a production chain, and the generated residues its exploitation do not have application for the aims pursued in this chapter.

According to the fiber classification proposed by Castellanos et al, the pineapple leaf is considered as hard fiber, and the stem bunch of plantain and banana, the rachis and mesocarp of oil palm are considered as soft fibers. In this sense, the statistics about world consumption of hard and soft fibers, and the potential employment of these types of fibers is significant; apparent world consumption of soft fibers in 2006 was about 2.8 million tons, whereas that same year hard fibers consumption reached near 550 thousand tons (ibid). This dynamic has been historically constant and let notices how the world demand of soft fibers exceeds the hard ones over 5 times, which results interesting in the considered proposal because most quantity of fibers considered as exploitable are configured by the soft ones.

Under this contextual framework previously expressed, it will be made the proposal for potential exploitation of biomass as feedstock for the end sought. In this regard Figure 4.1, Agricultural production of selected biomasses collects production data for agricultural products under study.

Products	Production (Ton/year)					
	2006	2007	2008	2009	2010	2011
Banana	1.786.727	1.863.592	2.045.825	1.984.044	1.977.218	1.802.407
Plantain	2.999.209	2.968.102	2.722.840	2.736.958	2.969.722	2.957.356
Pineapple	395.935	434.478	391.764	323.697	444.387	512.316
Rice[1]	2.410.397	2.455.264	2.749.663	3.028.947	2.449.006	2.245.936
Oil palm[2]	3.589.030	3.760.785	4.078.130	4.313.735	4.652.375	5.480.225
Sugarcane[3]	23.255.929	22.362.586	20.422.788	24.789.134	21.445.990	23.949.035

[1]This production includes manual and mechanized upland rice and irrigated rice .[2]The production was calculated based on production of oil for the same year dividing by a 0.2 factor according to the recommendation of Fedepalma.[3] the calculus corresponds to milled cane and it is including jaggery cane.

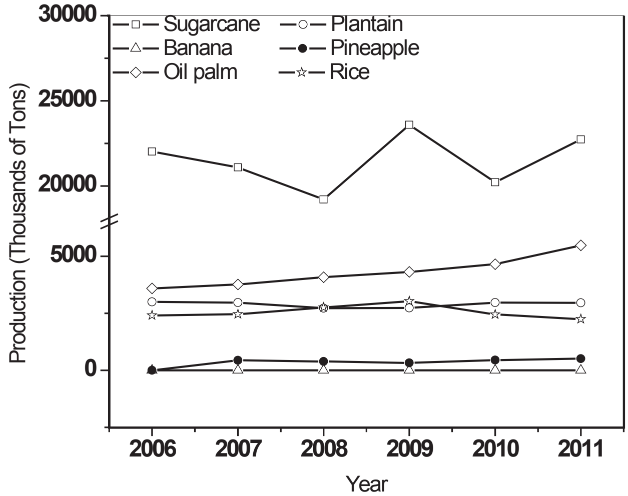
Source: Compiled data from Fedepalma (2012), MADR (2012)

In the data given in Table 4.1 when discussing banana, the statistics gathers the production of banana and exporting banana, the latter being more representative with participation by 2010 was approximately 86.3% of the national total for this crop.

Upland rice has been increasing its production, which has increased by 10.2% between 2008 and 2009; the irrigated rice production has also increased but with constant proportion and less evident. Nevertheless in 2011 the irrigated rice represented the 61.96 % of the total rice national production.

Regarding the sugar cane production, Table 4.1 collects data of sugar cane and jaggery cane. For 2011 sugar cane represented 95% of the country's total production, this crop had a significant rise in 2009 where the production was increased by almost 21% compared with 2008 production, the reason is perhaps the employment of sugar cane for generation of carburant alcohol, this situation brings as consequent for it to be one of major production crops nationwide.

Figure 4.1 Behavior of production of selected biomasses



The behavior of production of different selected biomasses showed in Figure 4.1 , exhibit a constant production for banana and pineapple, meanwhile oil palm, plantain and rice, the behavior of production change after 2009 and for sugar cane there is a little decrease in the production in 2008 compared with years before.

On the other hand, Table 4.2, Departments of major production in 2011, reflects where is gathered the major production of selected biomasses and the department participation in the total national production.

Equally, in table 4.2 just indicates the departments that gather the major quantity of national production, this selection is made due the aim, which is the proposal of implementation of production facilities of fibers or ashes, those departments with lower production should be dismiss because their volume production would not be enough for the plant implementation, and because the transport logistics towards other departments would make the operation unviable.

From table 4.2 is observed that Antioquia is the major banana producer, being more representative its production destined for exportation, for 2011 this department produced the 77.90 % of national total.

Table 4.2 Departments of major production in 2011

Product	Department	National Participation (%)
Banana	Antioquia	77.90
Plantain	Caldas, Risaralda, Quindío, Tolima	28.24
	Antioquia	8,99
Pineapple	Santander	53,78
Mechanized upland rice	Casanare , Meta	72.60
Irrigated rice	Tolima, Huila	54.46
Oil palm	Santander, Cesar, Magdalena	41.50
	Meta	33.70
Jaggary sugarcane	Santander, Cundinamarca, Boyacá	13.1
Sugarcane	Valle, Cauca	92,90

Source: Compiled data from AGRONET (2012)

Meanwhile, plantain production in 2011 was more distributed in several departments; nevertheless, Antioquia, Tolima, Caldas, and Quindío gather the 28.24% of the national production, being the latter department the one with major production with 10.73%. Antioquia meanwhile accounted for 8.91%.

In regard to pineapple, Santander was the major producer in 2011 with more than half of national production. It is also worth noting that Casanare and Meta produced in 2011 the 72.60 % of the total national production of upland rice, being Meta the higher producer with 38.1% of the total production, meanwhile Tolima and Huila produced more than half of the country irrigated rice.

Also in table 4.2 it can be observed that respecting to oil palm produced in 2011, it is distinguished two geographical sectors, on one side the high production of Meta which results important, and secondly, the production achieved in the upper and middle Magdalena, represented in the departments of Santander, Cesar and Magdalena which is quite significant.

Finally, in regard to sugarcane it is distinguished two geographical sectors, these comprised by the departments of the Cundinamarca-Boyacá plateau, where is implanted high jaggery sugarcane production and the department of Valle, which by tradition, production and performance, is pioneer with participation near 93% of national production, measured in 2011.

Table 4.3 Estimated Production of Fiber and ashes from selected biomasses

PRODUCT	RESIDUAL BIOMASS (%)	USEFUL FIBER (%)	USEFUL ASHES (%)	FIBER (Ton/year)	ASHES (Ton/year)
Banana	68	6-7 [f]	N.A	280.227	N.A
Plantain	68	6-7 [f]	N.A	424.363	N.A
Pineapple	61,4[a]	3 [g]	N.A	19,904	N.A
Rice	20 [b]	N.A	20[b]	N.A	102.261
Oil palm	79,4 [c]	N.A	5-10[c]	N.A	431.238
Sugar cane	26-29 [d]	N.A	2,8 [e]	N.A	968.588

[a] Araya, 1998), [b] Hwang et al, 2002), c IICA, 2010),[d] Roca Alarcón, et al [e] Reyes et al , [f] Peña et al, 2002),[g] Kengkhetkit et al , 2012)

In table 4.3, the production estimation of ash and fiber from selected biomasses, is indicated what would be the production projection considering as basis parameter the average of agricultural production from 2006 to 2011.

For purposes of clarity on the criteria under which table 4.3 was structured, here are suggested the considered variables on the table:

1. Residual quantity which is the ratio between the residues generated by the crop and the estimated total amount of crop, understood as biomass of which is sought to obtain the fiber or ash, plus the higher value added product

2. Data concerning usable fiber and ash are estimated through bibliographic referents and establish the percentage of biomass which would remain once it has been performed its modification.

3. The fiber and ash quantity is obtained by relating the residual quantity with the percentage of usable fiber and ash, the annual product production, the department or group of department's participation in the production of that product. This is the basis value of the proposal to implement.

From table 4.3 is concluded that the crop which generate the highest quantity of residual biomass are in their order the sugarcane, oil palm, the plantain, the rice husk, the banana and the pineapple; nonetheless the rice husk is the residual biomass that can provide the highest ash content, followed by oil palm, sugarcane, and jaggery cane.

The following sites are proposed as possible locations for fiber or ashes production plants.

PROPOSED PLANT LOCATION FOR OBTAINING FIBERS

From table 4.3, it can be observed in regard to usable fiber percentage, the potential of plantain double in production of fiber from banana and it is higher than the production of pineapple fiber production.

In regard to mentioned fibers, it can be established that he potential which the country has to generate its production is appreciable, of course it should be kept in mind that in the exercise are considered biomasses of which are achieved high levels of fiber content, but by its calorific value are used for energy production. The literature reports that the useful fiber % for oil palm and sugar cane, in the last one including jiggery cane, the values are between 13-15%, ACI (2001), these are sugarcane bagasse fiber which production to 2011 was near 772.000 ton/year, and its biomass for the Colombian case has a calorific value lower than 4.456 Kcal/Kg, With a energetic potential exceeding 76.000 TJ/year, Escalante (2010), the jaggery cane bagasse fiber which reached a production close to 24.000 ton/year, with a calorific value equal to sugar cane and a energy potential higher than 62.000 TJ/year (Ibid). From mesocarp and rachis of oil palm it can be obtained fibers in the range of 514.000 ton/year, which has an inferior calorific value that exceeds 12.000 Kcal/Kg and energetic potential higher than 16.000 TJ/year (ibid.).

As is established in table 4.3, these fibers have plenty potential to be produced on a industrial scale, nevertheless, as its main vocation is the energy generation, for purposes of this approach they will be considered only as ashes. In this context, the fibers that will be considered are the rachis and pseudostem of banana and plantain, and pineapple leaf.

In table 4.3 it is observed that the production potential of banana fiber, with a estimation based on the average agricultural production to 2011, would be near to 280.000 ton/year, also, in table 4.2 it is established that this production would belong to the department of Antioquia and it is located especially in northwest of it, which in addition is strategic because of its proximity to the Atlantic Ocean at the Urabá Gulf, enabling that the generation of both fiber and construction materials based on hydraulic cement matrixes have the possibility of being marketed within the country as be easily exported to low transportation cost.

In regard to plantain residual biomass, the possible quantity of fiber based on the average agricultural production between 2006 to 2011 is above 424.000 ton/year, checking table 4.2 it can be determined that this production is gathered in two zones, on one side the which brings together the departments of Tolima, Caldas, Risaralda, and Quindío, where the production plant could be located between the municipalities of Armenia and La Tebaida, which is a zone where is gathered an important quantity of production of the department of Quindío, and by its geographical position is close to the central south of the departments of Tolima, Risaralda and Caldas, and even it would include the production of the north zone from department of Valle del Cauca. Nevertheless, it would have to be evaluated the transportation cost to determine the final location and even the plant viability.

The other geographic zone proposed is the department of Antioquia; there the production is gathered in the northwestern part that is the same zone where banana is harvested, which could bolster even more the location proposal because it would include the fiber production from residual biomass of these two products.

In turn, the proposed plant for the production of fiber extracted from pineapple leaf is proposed to locate in municipalities at the north of the department of Santander, such as Rionegro, Girón, or Lebrija. The final location would be determine by the highway infrastructure and the routes between the site of plant location as a reception center and fiber production, and biomass collection centers located in the producer municipalities. Consequently it has to be evaluated the implied cost of collection, treatment, and transport, which are the variables that ultimately determines the viability of the plant.

PROPOSED PLANT LOCATION FOR OBTAINING BUILDING MATERIALS BY USING ASHES OR IMPROVEMENT THE SAME PLANT.

In the ashes case, the ultimate aim is not seeking its production from the proposed biomass, due to they come from process of energy generation that are gathered in the agroindustrial production centers, the aim is to use them in the generation of construction materials which its matrix is hydraulic cement, this is why it has to be tested the quality and quantity of the generated ash, and the process to improve its pozzolanic capacity. In this regard, it will be considered the proposal of use of ashes only considering the volume generated.

By analyzing the jaggery cane situation, is established that the sectors with higher production of the country are formed by the south of the department of Santander, Boyacá on the Suarez river basin, and the northwestern zone of Cundinamarca. Equally, in 2009 Colombia had 17.255 sugar mills, Portafolio, (2009), in 2010 there were near

39.961 jaggery producers, SIC, (2012), of which 12.784 were located in these three departments (*ibid.*).

This smallholder and disaggregated condition that makes for purposes of an industrial scale production, both construction materials as the ash improvement, that this biomass results unattractive and is not considered for the present proposal, due in terms of logistics becomes really expensive, and its collection and transportation unpractical, basic conditions to make viable any kind of industrial production.

In table 4.2 it is observed, in the case of rice, that the department of Meta, as previously mentioned, gathers the 41.8% of the national production of mechanized upland rice, and Casanare the 28.86% of this type of rice. Note that although these are bordering departments, the distance between the producer municipalities is the variable that makes to not consider them as a producer block, but rather as independent production departments. Under this consideration, the 31.536 ton/year of ash that potentially would produce these departments, 21.112 ton/year correspond to the department of Meta and the remaining amount to Casanare.

The Meta rice production is gathered in north of the department, in the municipalities of Puerto López, Cumarral y Cabuyero, Castilla la Nueva y San Carlos de Guaroa. Due the considerable distance between this municipalities it is suggested that the collection of ash in each municipal capital and its transportation to Villavicencio, there it could be located the production plant of construction materials or the plant for treatment and optimization of ashes.

In the Case of Casanare, the western municipalities of the department are the ones that gathered the production of mechanized upland rice; among them are Nuchía, San Luis de Palenque, Maní, Yopal, and Villa Nueva. Also, its situation is very similar to Meta, ergo, because of the distances between municipalities is required a collection in the municipal capital and the transportation of these ashes to Yopal, the city where the plant would be located.

In regard to irrigated rice, from table 4.2 it can be observed that the departments of Tolima and Huila generated in 2011 the highest country production with 54.46%. The Huila production was in the order of 14.12%, gathered in the central and north regions, in the municipalities of Campoalegre, Palermo, Villa Vieja, Tello, and Aipe. Regarding Tolima, the production was 40.34%, this located across the department standing out municipalities as Venadillo, Espinal, Saldaña, and Ibagué.

The plant implementation of the production of construction materials or treatment and optimization of ashes coming from the husk of this type of rice presents a similar situation that emerged with mechanized rice, that is more practical collect the ashes in the municipal capital, and transport them to Neiva, for Huila case, as Ibagué in the case of Tolima.

Now, in regard to the estimated production of ashes, and according to the recorded in table 4.3, for the case of Tolima the estimated quantity is in the order of 41.000 ton/year; for Huila it would be lower, near 14.000 ton/year.

In the case of biomasses come from palm oil, gathers over 78% of production in three zones, the first one located in the south of the department of Cesar and north of the department of Santander, with a ash production that can be estimated is near 129.113 ton/year; the second one located in north of the department of the department of Cesar and the east zone of the department of Magdalena, with a estimated production in the order of 103.290 ton/year; and the third one, the department of Meta, presenting a production estimated of over 154.935 ton/year; that would generate a total production of about 387.339 ton/year, which differs to the one indicated in Table 4.3, where the production is estimated for over 431.238 ton/year. The difference of just over 43.000 ton/year is because some municipalities are excluded by their distance to the centers of collection and transportation to the plant.

In south of the department of Cesar the municipalities with higher production are San Alberto and San Martín, which together with the north part of the department of Santander municipalities as Puerto Wilches, Sabana de Torres, and Rionegro, that would form a region with high potential for the implementation of the construction materials production plant or optimization of ashes.

The subregion that gathers the north of Cesar and the east of Magdalena includes the municipalities Aracataca, Fundación, Algarrobo, the former Banana Zone, El Retén, located in the department of Magdalena; and Codazzi, Copey, and Valledupar in the north zone of Cesar.

The third subregion is formed by the department of Meta, which has sown a large extension of its territory with oil palm; nonetheless, the municipalities of concern are San Martín, Castilla la Nueva, Acacias, San Carlos de Guaroay Cumarral. Some of these municipalities are producers of rice husk ash, which could make possible to consider combined strategies that allow the reduction of transport cost to Villavicencio, which is the city where the plant would be located, for the reasons outlined above about the mechanized rice.

Now, the last biomass to be evaluated is the sugarcane bagasse, which is certainly the most promising, and as is shown in table 4.3, has an estimated production of ash above the 968.000 ton/year representing almost the 65% of the estimated national total of ashes, its location would be in the department of Valle del Cauca, between the municipalities of Buga and Tuluá. In addition to the high level of production, it has in favor its proximity to the port of Buenaventura, which could make possible the exportation of fiber or ashes, or prefabricated construction materials.

CONCLUSIONS

Colombia for its geographic location, thermal floors diversity, and agricultural tradition, it offers a spectrum of possibilities for the establishment and expansion of crops with agricultural vocation, which generate high residues volume, and if they are properly treat afford the possibility of completely closing the production cycle, aspect that without any doubt contributes to the care and protection of the environment, creates jobs and contributes to the development of country.

This opportunity is enriched if are suggested solutions that allow the residual biomass be treat in a proper manner, for this it is necessary the construction of supply chains that are complex and require a design of logistic nets that address the problem considering all the variables interacting in the process, and ultimately are the ones that will allow the viability for the use and reintegration of biomass in the production chain.

In this chapter was evaluated the potential employment of residual biomass of agricultural crops implanted in the country, with the possibility of being used as fibers or ashes that can be introduced in a proper manner in hydraulic cement matrixes that allow to increase the materials life cycle destined to construction of housing and infrastructure, which contributes significantly to the improvement of the quality of life and development of the nation.

However, to make possible the achievement of the objective of proper insertion of this biomass it is required that the logistic net has to be proposed in a very detailed context, which evaluates and determine appropriate technical processes from the collection in the source, pretreatments that avoid the degradation of biomass, its proper use when is employed to energy generation in the production location, warehousing in the source, continuous supplying to the plant where is processed the biomass, this implicates a system design of efficient transport, in accordance with the local infrastructure state, energy consume evaluation and greenhouse gases emission in the whole process, and the most important, an precise evaluation of the cost associated to the optimization and adjustment of the production chain.

The entire operation has to be suggested considering a flexible chain, and be coupled to the own dynamics that are stamped by the market, the typical geopolitical condition of Colombian region, and the changeable state of the national road infrastructure, conditions which make to be required not only flexibility of the chain, but sturdiness of the same. The integral evaluation and ultimately the viability of the biomass employment for the production of construction materials will be possible if it is used the reverse logistics as tool to determinate the suitable operation, considering all the aspects that the chain requires, and it includes the holistic approach from the production source of the biomass to the generation of the construction material and its final commercialization.

In this chapter are proposed promising biomasses for their use as feedstock that combined with hydraulic cement allow the generation of competitive construction materials, remains open the space for logistics assessment through reverse logistics.

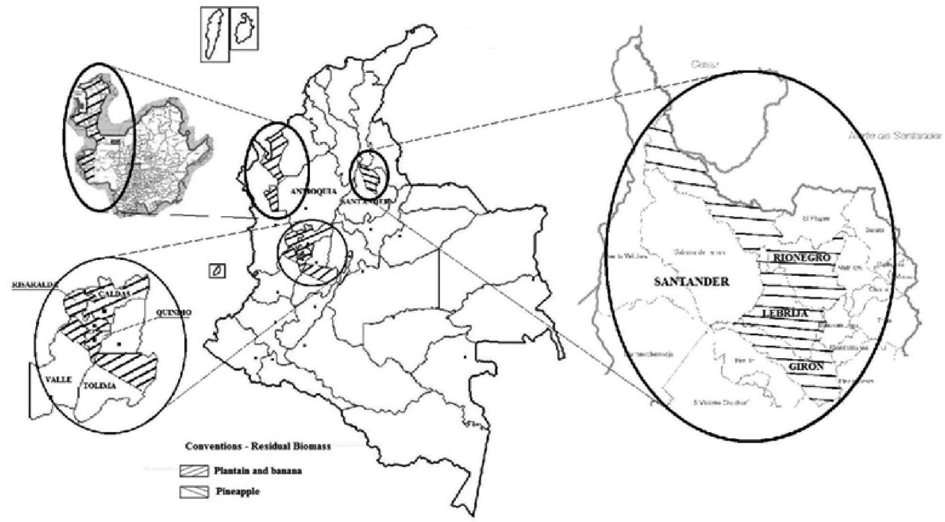
Now, of the evaluated biomasses, those in the case of utilization of the fiber were: the rachis and pseudostem of plantain and banana, pineapple leaf, oil palm extraction residues, sugarcane bagasse and jaggery cane bagasse, were made viable the plantain, banana and pineapple, were dismissed the oil palm, sugarcane, and jaggery cane bagasse because these biomasses are employed in high percentage for the obtaining of energy in the sugar factory, jaggery mill, and oil production plant.

Equally, to obtain of ash was evaluated the employment of rice husk, mesocarp and rachis from oil palm, sugarcane bagasse, and jaggery cane bagasse. The evaluation dismissed the jaggery cane bagasse due the low attractive of its employment, due to the condition of smallholder and scattered crop, which limits its use on an industrial scale.

The evaluation made in this chapter only were taken data from those departments where is gathered the bulk national agricultural production, ergo, the estimated numbers presented do not account the total that could be produce in the entire national territory, but the possible obtain of fibers and ashes in the departments which contribute the most to the agricultural production of each selected product of interest for its obtaining. Equally, for the estimation were taken data between 2006 to 2011.

Under this context, the Figure 4.2 shows the location of the fiber-producing plants. The potential production of fibers in Colombia could be above the 706.000 ton/year, a really interesting number that makes viable at least from the volume variable its implementation to industrial scale. In regard the department of Antioquia reaches a highly competitive level because the crops of plantain and banana gather in Urabá, which allows the implementation of a plant, that would process the fiber of both products, with a possibility to not only attend the national market but also the international, due its proximity to the Atlantic Ocean, is estimated a production near 276.000 ton/year.

Figure 4.2 Location of fiber producing plants



The other possible plant production of plantain fiber is proposed to be located in Calarcá (Quindío). This plant would gather the biomass of the departments of Caldas, Risaralda, the south central region of the departments of Tolima and Quindío, it would have a production estimated of 120.519 ton/year, nonetheless its final viability would have to be determinate once the supply chain and logistic operation viability is evaluated, in the setting of a proposal for integral action.

The last implementation proposal of fiber production plant would be assigned to the pineapple leaf fiber production, this would be located in north of the department of Santander, in municipalities as Rionegro, Girón, or Lebrija, its potential is lower, but not insignificant, and it is above 19.000 ton/year, as the proposed plant to the Eje Cafetero, its viability depends on the integral logistics assessment.

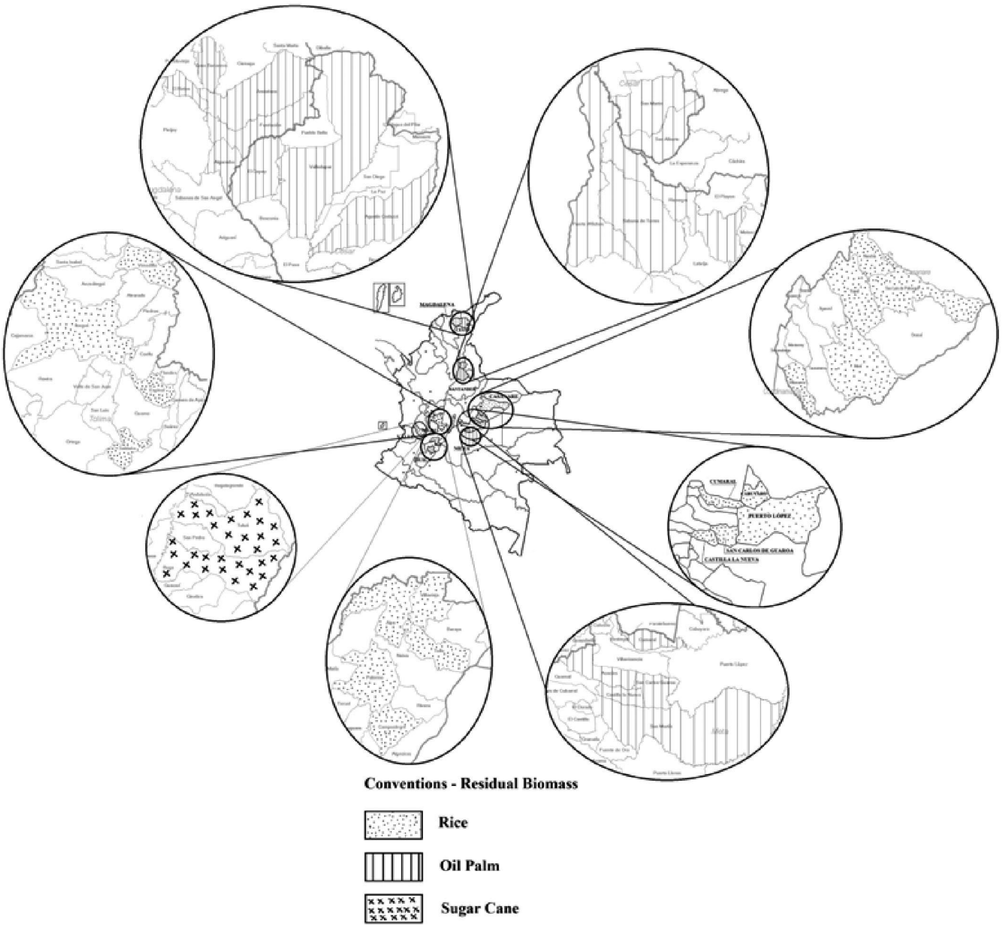
Regarding to ashes, the Figure 4.3 shows the location of the ash-producing plants. The estimated national production potential exceeds the 1.500.000 ton/year, for its improvement or use are proposed eight plants. In the case of rice husk ash 4 are required, which would be located in Ibague (Tolima), Neiva (Huila), Villavicencio (Meta), and Yopal (Casanare), with an estimated production capacity of 27.021. ton/year, 9.454 ton/year, 12.015 ton/year, and 10,879 ton/year, respectively.

Now, in the case of oil palm ashes are proposed three plants, one located between the south of Cesar and north of the department of Santander, other in the north of the department of Cesar and the central zone of the department of Magdalena, and the third one in the department of Meta, their productions would be in the order of 56.000 ton/year, 48.000 ton/year, and more than 145.000 ton/year, respectively. The location of the Meta plant would be in the city of Villavicencio, the location of the other two plants is followed of an integrated logistics analysis that would make viable the place.

The eighth plant, is the one that belongs to sugarcane bagasse ash, which would be located in the center of the department of Valle del Cauca, with a production potential of more than 800.000 ton/year and an aggregated advantage, the proximity to the port of Buenaventura, which make possible the exportation of fibers, or ashes as base feedstock, or prefabricated construction materials.

As it can be observed, results very attractive to locate the plants in the departments of Meta and Valle del Cauca, in Meta a factory would process around 157.000 ton/year of ash coming from the oil palm residues, and rice husks generated in the department; and in Valle del Cauca would be located the plant that more opportunities would have, due the estimated production of ashes of the department, as previously commented exceeds the 800.000 ton/year, configuring itself as the highest at national level.

Figure 4.3 Location of Ash producing plants



As can be deducted, the production potential of fibers and ashes can that have the country is high, the implementation of production plants of feedstock, or prefabricated composite materials or not, based on hydraulic cement matrixes is promising. This is a really interesting option because it would promote the employment generation, both rural and urban level, the impact would be more interesting in the rural zone, and it would help to stop the decrease in agricultural employment rate that the country has been suffering in the last 10 years, as also the poverty and marginal rate faced by many Colombian farmers.

Other aspect of interest is the one related to the economical impact of this proposal, which not only would help to decrease the poverty and unemployment rates, but it would affect positively the GDP, improving the participation of agriculture, a sector that has been losing space the national representativeness, as the construction, which it would increase its contribution to the GDP.

Furthermore, while using biomass that is just a byproduct of the agroindustrial production, it contributes to generate a cleaner agricultural production, decreasing the cost in the composite material because the employment of residues that today do not have a high value added, and well studied and measured out, increase the performance mechanical properties of the material, as the same as its durability, which affects directly in the life cycle increase of the edification and infrastructure, improving the national competitiveness.

The potential of agricultural and agroindustrial production that Colombia has is high, considering that the cultivated land in the national territory is quite low compared to the large area of land that has not been cultivated or is dedicated to livestock work. The establishment of this type of plants would certainly generate a relevant production dynamic which would affect the countryside positively, and would allow the land use with agricultural potential.

The nation challenges should be guided to consolidate an appropriate agrarian politic that allows the suitable land exploitation, complex aspect because the interaction of illegal armed groups who have favored the rural ousting and promoting the low usage of land.

The nation must additionally generate politics and strategies that allow it to change from being an agricultural to an agroindustrial producer; that guaranties welfare, competitiveness, and wealth generation. All these challenges depend on having more people with higher levels of knowledge, to pull with their ideas and projects, the country development, in addition of having appropriate road infrastructure, thus preventing production capacity and commercialization of new products of being dampened.

Finally, all this process should be supported through the giving of investment conditions which allow the investors to develop industrial plant implantation projects, also it should be favored combined strategies from the reverse logistics to encourage the resource exploitation from the perspective of shared logistics, which would result really useful in those proposals of collection, transport, processing, commercialization, that involve the participation of several departments and even producing municipalities.

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CHAPTER 5

SUPPLY CHAIN MANAGEMENT ANALYSIS IN THE PRODUCTION OF BIOPOLYMERS: A CASE STUDY ON POLYHYDROXYBUTYRATE

Javier M. Naranjo
Juan C. Higuita

Universidad Nacional de Colombia Sede Manizales

INTRODUCTION

Civilizations have throughout history looked for supplying their three mainly requirements: food security, energy and materials. Thus, mankind have used and transformed biotic and a-biotic resources from the environment. The biotic resources consist on every living part of earth, basically microorganisms, plants and animals. A-biotic resources are the other lifeless elements present on earth.
In the beginning of men's history, biomass (biotic resources) supplied part of all the basic needs: food, (e.g. crops, animals), energy (e.g. wood, charcoal) and materials (basically wood and animal skin).

Food security is one of the most important aspects for civilizations and guaranties their subsistence. This need encouraged sedentary civilizations to use their knowledge of the biotic resources to develop technologies for the intensive culture of some nutritional crops and the breeding of domestic animals (e.g. pigs, poultry and cattle). These developed technologies also included the use of some a-biotic resources (water and land), and have prevailed to present time.

The use of energy has been a crucial aspect for the development of civilizations because it has helped the control and adaptation to the environment. The energy sources refer to the usable energy that can be converted into other classes of energy or work for a particular practical purpose. During many years (until the industrial revolution) energy was used basically to supply basic needs such as cooking, warming, cooling, lightning, and some manufactory and transportation processes. The main energy sources were biomass for combustion (e.g. wood, charcoal, peat, straw, dried dung, and animal oil) and animal and human forces as work sources and transportation. Some a-biotic sources of energy were used such as sun (for light and warmth), wind (for force and transportation) and water (for force). There are two important energy transitions that revolutionized the civilizations: The change from the wood to coal (in England in 1700s) and the changed from coal to oil (McLamb, 2008). The 21st century will be characterized by a major shift in energy sources with a gradual obsolescence of fossil fuels, like coal and oil, for more efficient fossil fuels such as natural gas. Advances in biotechnologies let anticipate the growing usage of biofuels. Nuclear energy, particularly if nuclear fusion becomes commercially possible, may also play a significant role. Nowadays, some alternative sources are in development such as wind, hydrogen, geothermal and solar energy.

Similar to energy, materials have shown a similar development throughout history and have been fundamental to the living of civilization since the beginning of human kind. Anthropologists define the historical epochs by the main materials used by different civilizations such as Stone, Copper, Bronze and Iron ages. Nevertheless, other type of materials such as wood, ceramics, fibers, glass, aluminum have also been traditionally used by men In 1900s, a new class of artificial substances that have interesting properties was developed, namely plastics. The diversity of plastics and the versatility of their properties facilitate the production of a vast array of plastic products that bring technological advances, energy savings and numerous other societal benefits. Polymers are the newcomers among the bulk of the materials used in modern economies. They have been used in substantial quantities for only five to seven decades. In the next three decades plastics are expected to gain important segments of the glass market and to substitute, to a lesser extent, steel (Fossil Energ study guidesy, 2012). The production of plastics has increased substantially over the last 60 years from around 0.5 million tons in 1950 to over 260 million tons today. In Europe the plastic industry has a turnover in excess of 300 million Euros and employs 1.6 million people (Shen, L. et al., 2009).

The current energy and plastic sources depend on oil. Petroleum and its derivatives represent almost 35% of the total primary energy supply in the world and about 60% is employed in the transport sector (Cardona C.A. et al., 2010). However, the production of these types of energy and materials depends on the availability of oil, the increase of oil prices, the limited reserves of fossil fuels and the political instability in oil producer countries. Their intensive use has generated negative impacts to the environment producing Green House Gases (GHG) and Global Warming. The use of oil as fuel (gasoline and diesel) is changing with the incorporation of biofuels. Moreover, alternative energies have been researched and the world's technological development intensifies for the implementation of other energetic schemes.

In the case of the synthetic polymers, there are several options to reduce the environmental impacts related to their production and use. Some of the proposed strategies to reduce the environmental impact are: i) increased energy efficiency and material efficiency (yields) in all processes in the production chain leading to polymers; ii) increased end-use material efficiency, i.e., ensuring the same product service bylower amounts of material (e.g. by use of thinner plastic films); or iii) improved waste management by recycling of materials, re-use of productcomponents, energy recovery in waste-to-energy facilities (incineration) and - in thecase of biodegradable polymers – digestion (with energy recovery) and composting (Shen, L. et al.,2009).

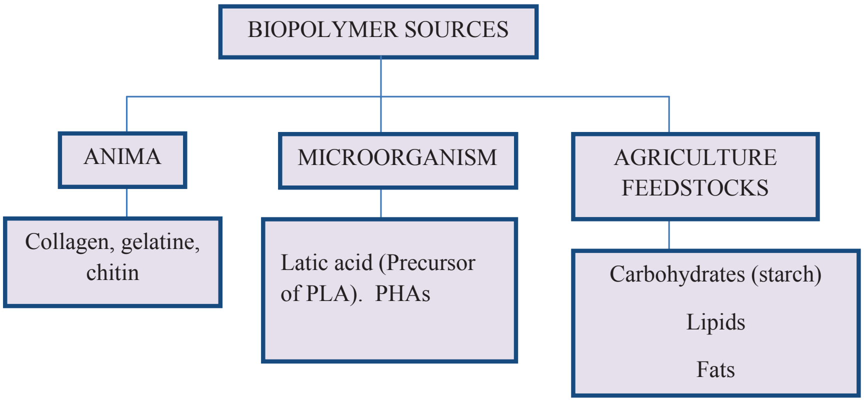
Bio-based materials are interesting alternatives for a reduction in the negative environmental impacts. They can be made from renewable sources and in their life cycle the carbon footprint can be decreased when compared to synthetic polymers.

BIOPOLYMERS

The name biopolymers is currently used for polymers that are either synthesized by living organisms or produced from substrates obtained from living organisms. Biopolymers are usually divided in two main classes and examples of the first kind of biopolymers are naturally occurring polymers such as cellulose, starch, and polyhydroxyalkanoates (PHAs). Among the second kind of polymers, is the poly-lactic acid that can be synthesized from biologically-obtained lactic acid, or even polyethylene, when it is produced from ethylene obtained from bio-ethanol. Bioplastics are biopolymers with plastic properties (Song, et al., 2009).

Biopolymers are derived from four main feedstock areas such as: i) Animal sources which provide collagen and gelatin, while marine sources provide chitin which is processed into chitosan;ii) Microbial metabolites like lactic acid are able to be transformed into poly-lactic acid (PLA) and PHAs (Gomez, J.G.C et al., 2012) and iii) Agricultural feedstocks are sources of biopolymers such as carbohydrates, lipids and fats that can be converted into biopolymers by microorganisms or via chemical synthesis (Figure 5.1).

Figure 5.1.Biopolymer sources



The first polymers used by men were derived from biomass resources (e.g., animal bones, horns and hooves, celluloid, casein plastics). However, they were displaced by petrochemical polymers parallel to the growth of the petrochemical industry in the 1930s. When the oil price increased in the 1970s, an interest in the possibilities offered by non-petrochemical feedstocks arose. Currently, there is a range of biopolymers with an interesting potential to substitute the synthetic polymers. As shown in Table 1, biopolymers can be of different types, such as: polysaccharides, polyesters, polyurethanes and polyamides.

Table 5.1.The Main bio-based polymer produced in large scale.

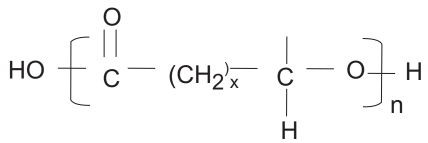
Biobased polymer	Type of polymer	Structure/Production
Starch polymers	Polysaccharides	Modified natural polymer
Cellulose polymers	Polysaccharides	a) Modified natural polymer b)Bacterial cellulose by fermentation
Polilactic Acid (PLA)	Polyester	Bio-based monomer (lactic acid) by fermentation, followed by polymerization
Polyhydroxylakanoates (PHAs)	Polyester	Direct production of polymer by fermentation or in a crop (usually genetic engineering)
Polyurethanes (PUR)	Polyurethanes	React polyol with isocyanate. Bio-based polyol can be produced from vegetable oils.
Polyamides (PA)	Polyamide	Bio-based monomer 11-aminoundecanoic acid from castor oil; Bio-based adipic acid by fermentation

Polyhydroxyalkanoates (PHAs)

Polyhydroxyalkanoates (PHAs) constitute a class of bio-based polyesters with highly attractive qualities for thermo-processing applications which is on the edge of mass production. Whereas PLA production is a two-stage process (fermentation to monomer followed by a conventional polymerization step), PHAs are produced directly via fermentation of carbon substrates within the microorganism. The PHAs are accumulated as granules within the cytoplasm of cells and serve as a microbial energy reserve material (Gomez, J.G.C et al., 2012).

Figure 5.2 shows the generic formula for PHAs where "n" is the number of monomers and "R" can be either hydrogen or hydrocarbon chains of up to 16 carbon molecules in length.

Figure 5.2. PHA molecule



A wide range of PHA homopolymers, copolymers, and heteropolymers have been produced, in most cases, at the laboratory scale. A few of them have attracted industrial interest and have been commercialized in the past decade. The main members of the PHA family are:

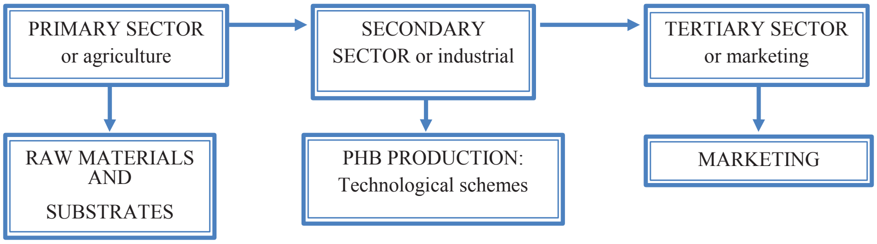
- poly(3-hydroxybutyrate), P(3HB), generic formula with R=1 (methyl);
- poly(3-hydroxyvalerate), P(3HV), generic formula with R=2 (ethyl);
- poly(3-hydroxyhexanoate), P(3HHx), generic formula with R=3 (propyl);
- poly (3-hydroxyoctanoate), P(3HO), generic formula with R=5 (pentyl);
- poly(3-hydroxydecanoate), P(3HD), generic formula with R=7 (heptyl); and
- the medium-chain-length poly(3HOd), generic formula with R=15.

Polyhydroxybutyrate (PHB) was the first type of PHAs discovered in 1926 by Lemoigne (Doi, Y., 1992) and is the most widely studied. PHB is produced, molded and, after a period of use, discarded and transformed into compost thus completing the natural cycle. PHB is a biocompatible, biodegradable, thermoplastic, hydrophobic, and stereospecific material. It has a high molecular mass, high crystallinity (55 to 75%), good chemical resistance, and its barrier properties enable practical packaging applications (Koning, G.J.M.,1993; Sudesh K. et al.,2000). PHB has similar mechanical properties to conventional plastics like polypropylene or polyethylene, but its production costs are higher than the petrochemical plastics. PHB can be synthesized and intracellularly stored by many bacteria in the form of granules and can account for up to 80% of the total bacterial dry weight (Khanna, S & Srivastava A., 2006; Mahishi, L.H et al., 2003). However, the massive production and marketing of PHB is limited by the production costs. Improvements in the production processes require a search for alternative new raw materials, design of pretreatment techniques and improvement in the fermentation and separation steps. These aspects will be further analyzed in the supply chain management section.

SUPPLY CHAIN MANAGEMENT IN THE PRODUCTION OF PHB

Supply chain management is the chain that links each element of the manufacture and supply process from raw materials to the end user. Thus, supply chain management considers the entire value chain and addresses materials and supply management beginning with the extraction of raw materials to the end of the final product'suseful life. Supply chain management focuses on how companies utilize their suppliers' processes, technology, and capability to enhance competitive advantage and the coordination of the manufacturing, logistics, and materials management functions within an organization. This analysis permits to understand the role of the economy sectors in the production of a product or service (Figure 5.3).

Figure 5.3. Sectors involved in the Supply chain management



PHB production includes the use of agro-industrial raw materials, the microbiological conversion of these raw materials into PHB, the separation and purification process of the PHB pellet, the transformation of this pellet into the final bioplastic product, the commercialization and marketing of the bioplastic and the final use of the product. All these steps in the PHB production can be analyzed throughout the supply chain management analysis in three economic sectors.

Primary sector:

The primary sector includes the production of raw materials and basic foods. Some activities associated with the primary sector include agriculture (both subsistence and commercial), mining, forestry, farming, grazing, hunting and gathering, fishing, and quarrying.

Agroindustrial raw materials can be classified also into three main groups, namely: first generation, second generation and third generation (Table 5.2).Currently, the substrates used for the production PHB are the first generation of raw materials. PHB can be produced from raw materials that contain different type of biomolecules such as: fermentable simple sugars (e.g. sucrose, maltose, glucose, and fructose), polysaccharides (e.g. starch, cellulose, and hemicelluloses), alcohols (e.g. glycerol) and volatile fatty acids (See Table 5.3).

Table 5.2. Classification of raw materials for PHB production

Raw material	Description	Examples
First generation	These feedstocks compete directly with food security because they are food crops and/or its production occupies lands that may be used for food production. When producing PHB from maize (made up from starch chains) or sugarcane (in the form of either cane juice or molasses) the raw material constitutes about 40–70% of the production cost	Energetic crops such as sugar cane, sugar beet, corn, soy bean
Second generation	This type of raw materials does not compete with food security. They can be crops as straw, grass, wood and agro-industrial, industrial or domestic wastes. The advantage of these feedstocks for PHB production is their low prices, but the disadvantages are the pretreatment processes (as shredding, densifying, pulverizing, handling and hydrolysis) and transportation.	Crops: straw, grass, wood. Agroindustrial wastes: whey, glycerol, lignocellulosic materials

Third generation	Raw materials derived from microalgae. They are considered to be viable alternative energy resources that are devoid of the major drawbacks associated with first and second generation biofuels. Microalgae are used specially for biodiesel production due to their capability to render 15–300 times more oil than traditional crops on an area basis. The resulting cake from microalgal growth is rich in carbohydrates that may be fermented for PHB production (Jaramillo, J.J. et al.,2012)	Starch from the microalgae *Chlorella vulgaris*.

Table 5.3.Type of raw materials for PHB production according to the characteristics of their components

Raw material		Description	Examples
Carbohydrates	Sugar-rich Material	Agroindustrial products where simple sugar compounds can be directly extracted.	Energetic crops such as sugar cane and sugar beets. Milk and its derivatives such as whey
	Starchy Material	Starch is a polymer exclusively composed by glucose units. In most cases, its conversion to PHB requires the hydrolysis of starch into glucose.	Corn, wheat, rye, barley, triticale, sorghum, tubercles.
	LignocellulosicBiomass	Lignocellulosic material consists of mainly three different types of polymers, namely cellulose, hemicellulose and lignin, which are associated which each other. Cellulose is composed by D-glucose subunits, linked by -1,4glycosidic bonds. Hemicellulose is a complex carbohydrate structure that consists of different polymers like pentoses (i.e., xylose and arabinose), hexoses (like mannose, glucose and galactose), and sugar acids. Lignin is an amorphous heteropolymerconsisting of three different phenylpropane units that are held together by different kinds of linkages.	Crop residues (cane bagasse, corn stover, wheat straw, rice straw, rice husk, barley straw, sweet sorghum bagasse, olive stones and pulp), hardwood (aspen, poplar), softwood (pine, spruce), cellulose wastes (newsprint, waste office paper, recycled paper sludge), herbaceous biomass (alfalfa hay, switchgrass, reed canary grass, coastal Bermudagrass, thimothy grass), and municipal solid wastes (MSW).
The first polymers used by men were derived from biomass resources (e.g., animal bones, horns and hooves, celluloid, casein plastics). However		The first polymers used by men were derived from biomass resources (e.g., animal bones, horns and hooves, celluloid, casein plastics). However	The first polymers used by men were derived from biomass resources (e.g., animal bones, horns and hooves, celluloid, casein plastics). However
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Feedstocks currently being utilized for PHA production are high value substrates such as sucrose, vegetable oils and fatty acids. In theory, any carbon source can be utilized, including lignocellulosic materials from agricultural by-products.

In the Unites States, a typical raw material source for PHB production is corn steep liquor; in the European Union (EU) beet sugar is more common; and in Brazil cane sugar is the main source. High value feedstocks such as palm kernel or soybean oil are also used with some microorganisms. The use of less expensive carbon sources would then bring down the biopolymer production cost.

Secondary Sector:

It consists in the manufacturing and production processes. Today PHAs are still in an early stage of industrial production, although it has been for decades an area of intensive Research and Development (R&D) (Shen, L. et al., 2009). Some companies have continued these efforts with the goal to bringimg PHAs to the market. Table 5.4 shows the main PHA producers and their locations

Table 5.4. The main PHA producers

Company	Location	Raw material	PHAs	Tradename	Stage/scale
Tianan	China	Corn sugar	P(3HB-co-3HV)	Enmat	Industrial
Telles	United States	Corn sugar	PHB copolymers	Mirel	Industrial
Kaneka	Japan	Vegetable oils	P(3HB-3HHx)	Kaneka	Pilot (announced) industrial
Green Bio/DSM	China	Sugar (unspecified)	P(3HB-co-4HB)	Green Bio	R&D, & (announced) industrial
PHB industrial	Brazil	Cane sugar	P(3HB) P(3HB-co-3HV)	Biocycle	R&D, Pilot & (announced) industrial
Biomer	Germany	Sugar (sucrose)	P(3HB)	Biomer	R&D, Pilot
Mitsubishi Gas Chemical	Japan	Methanol (from nature gas)	P(3HB)	Biogreen	R&D, Pilot
Biomatera	Canada	Sugar (unspecified)	P(3HB-co-3HV)	Biomatera	R&D, Pilot
Meredian	Unites States	Corn sugar	n/a	-	(announced) industrial
Tepha	Unites States	n/a	n/a	TephaFlez, TephaElast	R&D, Pilot
Tianzhu	China	n/a	P(3HB-co-HHx)	Tianzhu	R&D, Pilot

PHB can be bio-synthesized in vivo or in vitro forms. In vitro biosynthesis of PHB can be made from lactones or hydroxyalkanoic acids employing isolated lipases, esterases or even proteases. Synthetic-hydroxyacyl-CoA thioesters have been used also for the in vitro production of PHAs. In vitro PHA biosynthesis will reveal important features of PHA-granule formation and contribute to knowledge of the catalytic mechanisms of PHA synthases (Steinbüchel A. et al., 1998). In addition, in vitro processes will allow the synthesis of novel polyesters; novel constituents may be incorporated into PHAs because the synthesis is notrestricted to the capability of a microorganism's metabolism to provide hydroxyacyl-CoA thioesters. In addition, true block copolyesters may be synthesized that are not available by in vivo biosynthesis because of the slowness of the metabolism (Steinbüchel A. et al., 1998).

PHB can be produced in vivo by microorganisms or transgenic plants. The availability of bacterial genes for PHA biosynthesis and the knowledge of their structures, as well as the structure of PHA inclusions and the availability of sophisticated methods of plant molecular biotechnology, have enabled the production of PHAs in transgenic plants (Steinbüchel A. et al., 1998). The aim in these genetically modified plants is to reach with PHB a similar behavior like that presented with the natural compounds such as sucrose, starch or triacylglycerols in terms of efficiencies, storage and relatively easy extraction from their tissues. Stainbüchel (Steinbüchel A. et al., 1998) affirms that efficient and environmentally friendly extraction of PHB from large scale biological sources, such as agricultural crops, is not a trivial task. It cannot simply be squeezed out of the crops by mechanical pressing in a similar way to the separation of vegetable oils from oil seeds. Thus, the current microbiological production process of PHB, which consists of at least five steps, could be reduced to just two steps if extracted from transgenic plants. This will considerably reduce both the production time and the acreage required, for only approximately 25% of the plants will be required to produce the same amount of PHB. If these prerequisites are achieved, then the production of PHB at production costs similar to those for the extraction of natural storage products will be possible. On the basis of market prices for corn starch, soy-bean oil, sucrose and glucose of between US$0.25–0.50 kg, PHB) may be produced at less than US$0.5 kg (Steinbüchel A. et al., 1998). However, the PHB production by transgenic plants is still under research and development, and the use of productive lands for the production of biopolymers is in discussion.

An In vivo PHB production process by bacterial fermentation has the following main steps: (i) adaptation of substrate and inoculation, (ii) fermentation, and (iii) isolation and purification (including blending and pelletizing) (McLamb,2008). In the adaptation of substrate and inoculationthestrain must be adapted in a specific medium which contains the substrate. Thus, the microorganisms are activated and adapted to the fermentation media.

Bacteria used for PHAs production can be divided into two groups based on their culture conditions. The first group requireslimitation of an essential nutrient such as N, P, Mg, K, O or S, and excess of a carbon source; some of these bacterial strains are Bacillus megaterium, Cupriavidus necator, Alcaligenes eutrophus, Pseudomonas extorquens, and Pseudomonas oleovorans. In the secondgroup, nutrient limitation is not required and the polymer canbe accumulated during the growth phase; some examples are Escherichia coli(recombinant), Azotobacter vinelandii (recombinant),and Alcaligenes latus (Posada,J.A. et al., 2010).

The fermentation stage can be performed in different operational modes. Batch PHB production is normally induced by co-culturing the cells (Ganduri, V.S.R.K et al., 2005) or by limiting them with nitrogen availabilityusing an excess of carbon source in the stationary phase (Khanna S, & Srivastava AK., 2010). To induce the desired nutrient limitation and to achieve ahigh cell density, a fed-batch process is the most commonly used method (Shahhosseini, S.,2004) (Khanna, S., Srivastava, A.K., 2006). Thus, cell growth is maintained without nutrient limitation until a desired concentration is achieved. Then, an essentialnutrient is limited to allow an efficient PHB synthesis. During this nutrient limitation stage the residual cell concentration (i.e., the difference between cell concentration and polymer concentration) remains almost constant and cell concentration increases only by polymeric intracellular accumulation (Lee, SY.,1996). . For bacteria requiringan essential nutrient limitation, a two-stage chemostat should be employed thus resulting in a 1.7-fold higher productivity compared to the one-stage chemostat (Grothe, E., 1999). Culture performance is affected by several variables including temperature, pH, fed carbon to nitrogen ratio, concentration of substrates and trace elements, ionic strength, agitation intensity, and dissolved oxygen. To substantially enhance the yield and productivity of many bioprocesses, optimization (Grothe, E., 1999) (Khanna, S., Srivastava, A.K. 2005) and control of the fermentation conditions (Dias, J.M.L, 2009) have been used.

After fermentation, the next step is PHB isolation and purification. PHB must be extracted from the cell cytoplasm. Cell membrane is broken and PHB is dissolved and separated from the residual biomass (Posada,J.A. et al., 2010). The separation step can be divided in three parts: pretreatment, extraction, and purification. In the pretreatment step cell disruption is carried out easily and some alternatives for this stepare: heat, alkaline or salt pretreatment and freezing (Jacquel, N., 2008). Some of the different extraction methods to separate PHB from the cell residual material are: solvent extraction, digestion, mechanical cell disruption, supercritical fluids extraction, cellfragility and spontaneous liberation. Solvent extraction modifies the cell membrane permeabilityand the PHB is then dissolved (Tamer, M., 1998). Some used solvents are: chlorinated hydrocarbon (e.g., chloroform), cyclic carbonates (e.g., propylene and ethylene carbonates), halogenated solvents (e.g., chloroethanes and chloropropanes), non-halogenated solvents(e.g., chain (4–10 carbons) alcohols, esters, amides, andketones (both cyclic and acyclic compounds). Digestion can be chemically or enzymatically performed. Chemical digestion uses different chemical agents to destroy lipids, carbohydrates, proteins and enzymes. According to the chemical agent used, the chemicaldigestion could be: digestion by surfactants (e.g., anionic sodiumdodecyl sulfate (SDS) and synthetic palmitoylcarnitine), by sodium hypochlorite, by sodium hypochlorite and chloroform, surfactanthypochloritedigestion, surfactant-chelate digestion, and selectivedissolution of non-PHA cell mass by protons. The enzymatic digestion uses enzymes to degrade the cell membrane. Some varieties of proteolytic enzymes have high activities on protein dissolutionsand slight effects on PHB degradation. Enzymatic digestion can be complemented by other extraction methods. Mechanical cell disruptionhas been widely used to recover intracellular proteins by different ways (Chen, Y. et al., 2003) (Hejazi, P. et al., 2003) such as: bead mill disruption, high pressure homogenization, disruption by ultrasonication, centrifugation, and chemical treatment. Supercritical fluids have unique physicochemical properties such as high densities and low viscosities that make them suitable as extraction solvents. Due to its low toxicity and reactivity, moderate critical temperature and pressure (31°C and 73 atm), availability, low cost, and nonflammability CO_2 is the most used fluid (Hejazi, P. et al., 2003). This extraction method can also be combined with NaOH or salt (NaCl) pretreatments to get higher disruption levels (Jacquel, N., 2008). Other extraction methods use air such as: air classification and dissolved-air flotation. Finally, purification methods involve a hydrogen peroxide treatment combined with action of enzymes or chelating agents (Jacquel, N., 2008).

The PHB production process considers the use of renewable raw materials, the microbiological conversions into PHB and the separation and purification processes.

Energy is obtained for PHB production from steam, electricity and natural gas. Steam is used for media sterilization, steaming out of the reactor vessel and backing steam. Electricity is used in agitation of reactors, cell disruption, centrifugation and the electrical requirement to pump air in aeration. Natural gas is used to provide energy to the spray drying process; energy which could also originate from other sources for different drying techniques. Handing et. al. (Harding,K.G. et al., 2003) show on an energy basis that the proportional contribution of steam, electricity and natural gas can be 67.7, 21.0 and 11.3%, respectively. This is a high steam requirement, predominantly originating from backing steam (78%). Opportunity for process optimization through both water and energy integration studies still exist (Harding,K.G. et al., 2003). Handing et. al. demonstrated that the total cradle-to-gate energy needed for the production of PHB was 42.9 MJ/kg polymer. This is made up of 41.4 MJ of non-renewable energy and 1.5 MJ renewable energy. This can be broken down as 18.8 MJ for PHB production and 24.1 MJ for raw material production (sucrose). This is lower than in previous studies and lower than the 73–85 MJ/kg-polymer for polypropylene (PP) and polyethylene (PE) production reported by Boustead (Boustead, I., 2000). Harding et. al. (Harding,K.G. et al., 2003) report that the current main inputs by mass of PHB production are steam and sucrose. A large amount of water is required, broken down as water for feed, additional makeup water in downstream processing and wash water used between batches (approximately three times reactor volume). This results in a large amount of wastewater and an associated chemical oxygen demand (COD). The dominant contributions to the environmental burden in the production of PHB are the large requirement for energy, in particular steam, as well as the high water requirement (65 dm3 per kg polymer). The use of fertilizer (from agricultural processes), acids and a significant number of salts, adds to the toxicity levels of wastewater and the eutrophication potential. Despite this, the production of polyhydroxybutyrate is more beneficial in a full cradle-to-gate life cycle assessment study than polypropylene production (Harding,K.G. et al., 2003).

After the PHA pellet is produced, it can be transformed into different final products. Today, commercially available PHAs can be used for injection molding, extrusion and paper coating. The injection molded and/or extruded PHA products cover a wide range of applications, such as cutlery, packaging (bags, boxes and foams), agriculture mulch films, personal care (razors and tooth brush handles), office supplies (pens), golf pins, toys and various household wares. PHAs can also be extruded into fibers. For instance, Biocycle offers PHA fibers that can be used for automobile carpets, dental floss and cigarette filters .Green Bio offers PHA fibers that can be used in non-woven applications. Today, packaging and agricultural films are the most important market for PHAs. In the future, the applications will become more diverse. PHAs are expected to gain market shares in buildings, textiles, transportation and houseware. Besides single-use disposable applications, producers of PHA also aim at durable products (e.g. bathroom accessories).

PHA is also a promising material for many novel applications where biodegradability and – increasingly - the use of renewable feedstocks are prerequisites that conventional synthetic thermoplastic polymers cannot meet. The current and future capacities of major PHA producers are listed in Table 5.5 The (potentially) largest producers of PHAs are the Japanese company Kaneka Co.,the US companies Telles and Meredian Inc., and the Chinese companies Tianan Biological Material Co. Ltd. and Tianjin Green BioSciences Ltd., which is a joint-venturewith DSM.

Table 5.5. Current and future capacities of the major PHA producers

Company	Trade names or products	Capacity 2010 (t.p.y)	Capacity in the future Announced (A) or Expected (E) 2020 t.p.y
Tianan	Enmat	10.000	50.000
Telles	Mirel	50.000	500.000
Kaneka	Kaneka (PHBH)	1.000	50.000
Green Bio/DSM	Green BIO	10.000	n/a
PHB Industrial	Biocycle	10.000	10.000
Mitsubishi Gas Chemical	Biogreen	n/a	n/a
Meredian	Meredian	n/a	272.000

t.p.y: ton per year
n/a: non applicable

At present, the raw material costs account for as much as 40% to 50% of the total production cost for PHA. Use of lower cost carbon sources, recombinant microorganisms or genetically engineered plants should all lead to reductions in production costs (DegliInnocenti, F.,& Bastioli, B. 2002).

Tertiary Sector

The tertiary sector of the economy services to the general population and to businesses. Some activities associated with this sector include retail and wholesale sales, transportation and distribution, entertainment (movies, television, radio, music, theater, etc.), restaurants, clerical services, media, tourism, insurance, banking, healthcare, and law .

Because of PHA's good performance in terms of biocompatibility and absorbability inhuman tissue, it can be used in the medical field including tissue engineering, wound healing, cardiovascular, orthopaedics and drug delivery. PHA suture, artificial esophagus andartificial blood vessels are currently offered as commercial products (Gomez, J.G.C et al., 2012) (Song, J.H et al., 2009).

The price of PHAs in general is presently much higher than starch plastics and other biobased polyesters due to high raw material costs, high processing costs (particularly the purification of the fermentation broth), and small production volumes. Some companies are working for decreasing the production costs making the PHB more competitive. For instance, Tianan expects that the sell price will drop to $3.52 /kg in 2020 along with their capacity expansions (Lunt, J.,2008). Kaneka expects the price of its PHBHx will drop to €3.40 /kg in 2020 (Kaneka , 2008).

Currently, synthetic plastic materials have a huge demand not only for their mechanical and physical properties but also for their sale prices (<0,5 USD/kg). The current sale prices of PHB are between 3.1 and 4.4 USD/kg, using sucrose and/or glucose as carbon sources (Posada,J.A. et al., 2010). In consequence, PHB can be from 6-8 fold more expensive than synthetic plastics. The production costs are the main obstacle in the PHB production at large scale and its demand is specially limited in Green markets. However, the search for less expensive substrates led to a decrease in the production costs and an increase in the economic viability of the process. In this way, several agroindustrial wastes have been studied as substrates for the production of PHB such as: glycerol, sugar cane residues, whey and sugar beet residues among others. The main challenges in the use of agroindustrial wastes as substrates in the production of PHB are: the gathering, transport, storage and pretreatment processes. However, if the polyhydroxybutyrate production is coupled into a biorefinery it could increase the economic and environmental availability of the process through energy and mass integration strategies thus making the logistic management simpler.

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CHAPTER 6

GREEN LOGISTICS, REVERSE LOGISTICS AND AGRO-INDUSTRIES: OVERVIEW OF SCIENTIFIC ARTICLES AND INTERNATIONAL PROGRAMS

João Luís de Miranda
María José Pinto da Silva Varadinov
Escola Superior de Tecnologia e Gestão, Instituto Politécnico de Portalegre

Sergio Rubio Lacoba.
Escuela de Ingenierías Industriales Universidad de Extremadura

Introduction

The research in the fields of green logistics and reverse logistics is quite recent, and new research topics still are being analyzed. Considering the knowledge triangle of education-research-innovation, research shall have straight impact either in higher education or in market innovation issues, supporting this way the construction of a knowledge-based economy, and fostering economic growth.

The knowledge triangle between education, research and innovation needs to be strengthened in order to maximize the contribution of EU higher education institutions to smart and sustainable growth. However, the effectiveness of higher education requires further improvements, either to be integrating the current results of research or to be updating the innovative practice. In plus, the exploitation of marketable products and services usually requires the construction of pathways into the academia-industry gap.

The point is to offer a closer relationship with higher education and research to the private sector companies. It is expected that this new relationship is bringing new opportunities to develop new products and services, thus enhancing life quality and EU competitiveness at global level.

Our purpose is thus to revisit the fundamental articles of literature review on the topic of green and reverse logistics, considering the approaches outlined in Rubio et al (2008) and Varadinov (2012), in order to: *i)* present guidelines about the topics that have been investigated; *ii)* analyse and compare the referred articles analysis and comparison of the referred articles; *iii)* point out aspects that have not been addressed in the literature; and iv) to gain insight about the future trends.

To better complete the approach, we are also addressing the international education programs and cooperation projects in green logistics and agro-industries, revisiting projects compendia, best practices reports, and the related databases. As outlined by Miranda (2013a, 2013b), a satisfactory real-time contribution is presented, being useful for academic and practitioners due to the relatively short lead-time for publication and dissemination of international programs.

This chapter is divided in five sections: in section two, general concepts concerning green and reverse logistics are presented; section three presents the main subject of the review articles at hand; in section four, a critical analysis concerning education programs and international cooperation in green logistics is developed; and finally, conclusions and main trends are presented in section five.

General concepts

In agro-industries, both harvest and transportation of raw materials, from the rural areas to the processing plants, are important aspects for the logistics systems. The need for greener logistics usually provokes hesitation on decision-makers to further invest in environmental friendly operations, namely when considering energetic crisis and proper energy balances along the agro-industry supply chain (SC).
Green logistics addresses the study of practices aiming at the reduction of environmental externalities, specially greenhouse gas emissions, noise, accidents, mitigating the impact of logistics operations, and to develop a

sustainable balance between economic, environmental and social subjects. The triangle of sustainable logistics thus integrates the three vertex economy-environment-society, being the current objectives of green logistics closely associated with these topics and far beyond the typical minimization of costs.

Closed-Loop Supply Chain (CLSC) and Reverse Logistics (RL) are considered to be environmentally friendly, and they generally integrate green logistics as key attributes. Instead of processing completely new products, RL is mainly related to products and parts made from discarded products and recycled materials, thus RL environmental effects are expected to be quite positive.

RL is a recent concept for many practitioners and is associated with the management and handling of equipment, products, components, materials or even all technical systems to be recovered. Environmental disasters that occurred in the 80s stimulated the adoption of measures to reduce the negative impact of human activity, namely: reducing wastes creation, encouraging recovery activities, and the recycling and reuse of products. These measures mostly result in constant changes in laws, rules, norms, and their implications for the transfer of responsibilities from consumers to manufacturers in the end-of-life's disposal.

RL has increased in importance both in practice and in academia (Stock, 1992; Kopicky, 1993, Fleischmann et al., 1997, Guide and Van Wassenhove, 2001), and the RL concept has not been precisely defined due to its rapid growth in importance. As stated in several authors (Fleischmann, 2000; Mason, 2002; Kivinen, 2002, Tan et al., 2002), still there is no broad consensus defining RL in practice. Various definitions are provided from:

- The Council of Logistics Management (Stock, 1992): "[...] the term often used to refer to the role of logistics in recycling, waste disposal and management of hazardous materials, a broad perspective includes everything that is related to logistics activities carried out in the depletion of resources, recycling, substitution, reuse of materials and disposal."
- The Reverse Logistics Executive Council "the process of moving goods from their point of final destination to another point, in order to get value that otherwise would not be possible, or for the proper disposal of products."
- Kivinen (2002): "[...] the management of any items (used or not, finished or simple components, parts or materials) that, for different kinds of reasons, are sent by a member of the supply chain for any former member of the same chain". Furthermore, he considered that flows outing the original supply chain but whose connection is located in the original range are also included, as result of the repair activities, the recovery of materials or value added.
- The European Working Group on Reverse Logistics - RevLog (1998): "[...] the process of planning, implementing and controlling flows of raw materials, in process inventory, and finished goods from point of manufacture, distribution or use for a recovery point or a point of proper disposal."

MAIN SUBJECTS OF THE REVIEW ARTICLES

The revisited literature in the field of green and reverse logistics includes all papers published in recent years in prestigious scientific journals from 2005, since this is considered the period of proliferation of articles (Pokharel and Mutha, 2009). We analyzed the main studies on green and reverse logistics, being examined in detail those from Varadinov (2012), Pokharel and Mutha (2009), Rubio et al. (2008), Meade et al. (2007), Srivastava (2007), Prahinski and Kocabasoglu (2006), and Dowlatshahi (2005). This approach allows the verification of aspects not yet investigated in green and reverse logistics, and to identify lines of research and future trends.

Analyzing the bibliography at the time, Dowlatshahi (2005) identified the state of theory through the formulation of proposals for strategic factors. His approach is based on grounded theory development, being grounded theory defined as a qualitative mode in which the theory is derived from the study of phenomena (Strauss and Corbin, 1998). The strategic factors are outlined and assessed in terms of specific sub-factors that are associated with each factor. Dowlatshahi (2005) used a survey protocol and his analysis considered two central questions, based in two different activities and business transactions associated with the reprocessing/recycling within the RL system:

1. What are the critical factors needed in the strategic development of an effective system for reverse logistics?
2. How should the company use these strategic factors for the implementation of reverse logistics systems with respect to reprocessing operations?

***Table 6.*1 Synopsis of review articles.**

Year	Authors	Subject
2005	Dowlatshahi	Development of strategic factors based on survey and grounded theory.
2006	Prahinski and Kocabasoglu	Concepts on RSC, development of research propositions.
2007	Meade et. al.	Overview of definitions, research and research opportunities.
2007	Srivastava	Integration of environmental issues in the SCM practice and research.
2008	Rubio et. al.	Analysis of RL main characteristics, construction of data-base.
2009	Pokharel and Mutha	Literature classification according to the RL system (inputs, processes, outputs and structures).
2012	Varadinov	Recompilation of review articles.

Prahinski and Kocabasoglu (2006) reviewed the literature on Reverse Supply Chain (RSC) and various research propositions are developed to be analyzed through empirical models. In addition, some reasons for the importance of the RSC study are pointed out:

- The amount of returned products is very high, with some industries reaching up to 50% of its sales returns;
- The sales opportunities in secondary and global markets increased the generation of financial income from products previously thrown out;
- The laws "end-of-life take-back" increased in the last decade, requiring attention to deal with the end-of-life products ;
- The consumers are pushing traders to take responsibility in the disposal of their products containing hazardous waste;
- The landfill capacity has become limited and expensive, and alternatives such repackaging, reprocessing and recycling are emerging out.

Meade et al. (2007) reviewed RL literature, and provided an overview of definitions, research and research opportunities. The purpose was to promote an updated literature on RL in a theoretical and practical perspective. Meade et al. (2007) highlighted some of the fundamentals and basic activities that organizations and researchers need to support, such as:

- The last stages of the organizational structure, and the improvements in RL management;
- The development of theory and standards to promote phenomena explanations and practice improvements;
- The incorporation of organizational, policy and behavioral researches in the field of methodologies application;
- The integration and carefully consideration of RL strategic and environmental implications;
- New perspective to be introduced into RL from globalization issues.

Srivastava (2007) referred to the necessity to integrate environmental choices in the practice and research of supply chain management. The literature shows that an outer frame of reference for the Green SC Management (GrSCM) was not properly developed. The objective was to provide an integrated review of the literature published in all facets of GrSCM, from a RL point of view , in order to facilitate further studies and research practices. Qualitative analysis was applied to classify the literature based on the problem context and the method / approach that is adopted. The vis-à-vis tools / techniques for the problem's context classification are also presented.
Srivastava (2007) aimed to identify important work in GrSCM research integrating environmental thinking into the management of the supply chain (Supply Chain Management - SCM), and ranked them in order to identify gaps, issues and opportunities for research. He considered that the GrSCM' scope moved from a reactive monitoring of environmental programs for general practice onto a more proactive implemented through multiple Rs (reduce, reuse, rework, refurbish, reclaim, recycle, remanufacture, reverse logistics). An overview of the topics and models was presented:

- Green Design (Zhang et al., 1997) – addressing Environmentally Conscious Design (ECD) and the Life-Cycle

Analysis (LCA) of the product;
- Green Operations (Guide et al., 1996); (Gungor and Gupta, 1999) - The challenges of GrSCM are the integration of remanufacturing internal operations, understand the effects of competition between re-fabricants, integrating product design, product take-back incentives, and integrating remanufacturing and RL with the design of the SC.

Moreover, Srivastava (2007) also analyzed the techniques and tools. Depending on the methodology used, the analysis of such techniques and tools aimed at the verification of applicability / adaptability within the GrSCM context. Considering that:

1. The choice of techniques and tools depends on several factors (nature of the problem, nature and availability of data, familiarity with the technical compatibility between the analysis and tools for the solution);
2. In the GrSCM integration are used a limited number of models (Analytic Hierarchy Process/Analytic Network Process - AHP/ANP, Regression, Data Envelopment Analysis-DEA, and descriptive statistics based on interviews / surveys);
3. Linear programming (LP) and non-linear programming (NLP) were used shortly;
4. Tools, techniques and mathematical methods were rarely applied in green design;
5. Some mixed-integer linear programming (MILP) formulations, software package and spreadsheets have been used in the solutions;
6. Manufacturing and green remanufacturing have been used with some frequency the tools, techniques and mathematical models;
7. In planning and production control, the dominant approach is to formulate problems using priority rules, followed by simulation to generate descriptive statistics for analysis;
8. RL models mostly focused on the network design using computer programming software and tools.

While Srivastava (2007) aimed at the identification of gaps and opportunities in GrSCM to outline further studies, by addressing mathematical models and avoiding operational issues, Rubio et al. (2008) made an analysis of the main studies on the RL concept, sorting them into three key areas. These key areas were identified using the classification of Dekker et al. (2004), and they are:

- Managing the recovery and distribution of end of life products;
- Managing the production planning and inventory; and
- Management of SC issues within the RL framework.

Rubio et al. (2008) described and analyzed the main characteristics of RL articles in the field of production and operations management, in order to determine the evolution of research over the last few years, and to improve or better understand the topic. They constructed a database of RL articles and explored the topic, the methodology, the analysis techniques, as well as other aspects. The result was a review of the works that have created and developed the RL concept, highlighting some directions for the future and offering practical help to future researchers. In conclusion, They suggested that research should be directed to the theory of strategic analysis and organizational development, establishing a framework in which the tactical and operational aspects can be efficiently developed.

Furthermore, Rubio et al. (2008) also noted that those studies employed methodologies that are either quantitative (mathematical models) and qualitative (case studies, literature review or theoretical developments). As a result of their analysis of tactical and operational decisions, they verified that the topic "Management of SC issues in RL" had attracted the attention of researchers. They also concluded that:

- The research has been led by scholars from The Netherlands, Germany and USA. The research was very recent and Rotterdan Erasmus University (The Netherlands) was the main institution in the articles publication;
- The articles focused on the study of tactical and operational aspects, such as the management of production planning and inventory derived from the RL implementation;
- Research on "Management of the recovery and distribution of products at end of life" was characterized as using quantitative and qualitative techniques, applying mathematical models and case studies;
- Research on "production planning and inventory management" has been characterized according to the quantitative behavior;
- Research on "Management of the SC in the context of RL" has been characterized as theoretical and qualitative, using the case study methodology.

While Rubio et al. (2008) made an analysis of the main characteristics of studies on the RL concept, Pokharel and Mutha (2009) analyzed the contents of a holistic system from the inputs to outputs and to the inputs again.

Pokharel and Mutha (2009) adopted the methodology of content analysis to identify literature in terms of different categories and they were limited to publications obtained through electronic source. The review showed that publications increased from 2005 and indicated the growing recognition of RL as a driver topic for research on SC and logistics. Finally, they concluded that RL research is multifaceted and different from the direct logistics.

They classified the content according to the RL' system: inputs, processes, outputs and structures. They pointed out that both research and practice are focusing all the RL aspects, from the collection of used products, structure, processes, and outputs (recycled materials, spare parts, remanufactured products and waste disposal). Namely, they referred the following topics as deserving further attention:

- Inputs and product recovery - Procedures to forecast the return of reusable containers; incentives to motivate the end-user to return the product; methods for calculating the optimal price for the acquisition and sale of remanufactured products;
- Structure – Most studies are related to location and allocation problems, system identification in the SC, inventory control, coordination, and use of modular structures;
- Processes – The coordination of planning and control in the remanufacturing process; the importance of communication in the fast and easy disposal of returned products; the issues of handling heterogeneous parts and the diversification of inventories;
- Outputs – The pricing of the remanufactured products, the relations and modeling of the markets for new products versus the remanufactured products; the costumers benefits and their satisfaction.

While Pokharel and Mutha (2009) investigated the development of RL research and RL practice through the analysis of articles found using web search engines, books, and conferences, Varadinov (2012) also reviewed RL scientific articles. Varadinov (2012) addressed the main characteristics of bibliographic recompilations, highlighting their commonalities and their differences. In that paper, various subjects were identified either as not fully developed or as deserving further developments, namely:

- Many of the references are general and practice-oriented, and do not provide a sound integration of RL topics, being also necessary to remove the interdisciplinary gaps in RL research;
- For practitioners, the design and management of RL networks could be facilitated by a reference model, but most of research was exploratory and there is a lack of grounded theories;
- The RL concept should be explored and integrated in the products life cycle, early from the products design to the late final consumer;
- Research should be directed onto theoretical subjects of strategic analysis and organizational development, establishing a framework in which the tactical and operational aspects can be developed;
- Research should support RSC managers in order to reduce the gap in-between customer expectations and his perception of service quality; and
- The need to develop pricing models for remanufactured products, considering either the product life cycle or the different levels of quality.

A recent article by Dekker et al. (2012) present some overlap with our overview, but we are taking a more focused RL perspective in this text. In addition, our structure is in concordance with the authors' research lines and the international programs we are developing, as presented in next section.

MAIN SUBJECTS ON INTERNATIONAL COOPERATION

The revisited education programs and cooperation projects in the field of green and reverse logistics consider as common attributes: the closer connection with industry and services companies at international or European level; the multidisciplinary approach and inter-organizational linkages; the focus on global competitiveness and efficiency in the resources utilization.

To better promote the knowledge triangle on education-research-innovation, several pilot projects were supported by the European Commission. The pilot project GAST-Green and Safe Road Transportation integrated education, research and innovation issues to achieve "greener and safer road transportation". For that, key players in these subjects are gathered, including suppliers for the vehicle industry and cooperation models are developed. Synoptically, the project GAST considered:

- The main challenges to cope are the growing demand of mobility for people and goods, environmental concerns, energy issues, and efficiency and competitiveness at global level.
- The approach then aimed at the needs of the transportation industry, namely, through collaborative education programs that provide graduates with adequate quantitative and qualitative tools; or by integrating educational aspects within project houses where innovation programs are jointly developed by industry and academia.
- Finally, the outcomes included the improvement of innovative practices by the EU industry, and the creation of business opportunities from the R&D activities.

Table 6.2 **Synopsis of international education programs and cooperation projects**

Year(s)	Acronym	Title
2007-2009	**EURO-QLIO**	Virtual course for the study of quality, industrial logistics and organization (3 partner countries, the minimum number)
2007-2009	**LSCM**	Curriculum development of Erasmus MSc. on Logistics and Supply Chain Management (6 partner countries)
2007-2009	**3-LENSUS**	Lifelong learning network for sustainable development (more than twenty partners, relevance in the field)
2007	**MYCORED**	Novel integrated strategies for worldwide mycotoxin reduction in the food and feed chains (worldwide partnership, global context)
	MAREX	Exploring Marine Resources for Bioactive Compounds: From Discovery to Sustainable Production and Industrial Applications.
2007-2009	**GAST**	Green and Safe Road Transportation (more than twenty partners, relevance in the field)
	SUSTAINMED	Sustainable agri-food systems and rural development in the Mediterranean partner countries
2009-(…)	**LSCM (Open-Course-Ware)**	Open course in Logistics and Supply Chain Management (Massive Open Online Course)
2011-(…)	**Odss.4SC**	Optimization and Decision support Systems for Supply Chain (7 partners, 1 global company)

One of the key points in current European programs and international cooperation projects is the interdisciplinary approach, the expertise and competence in multidisciplinary subjects, for instance, in agricultural and biological subjects. The ERABEE-TN-*Education and Research in Biosystems (Agricultural and Biological) Engineering in Europe* is a thematic network focusing the emerging discipline of Biosystems (Agricultural and Biological) Engineering in Europe, and among others, with an appealing outcome of enrolling highly skilled students from abroad. To achieve it, several tasks related with the recognition and accreditation are foreseen at European and international level, mobility issues are addressed, and sustainability practices are focused.

Similarly, the Erasmus Network 3LENSUS-Lifelong Learning Network for Sustainable Development is developed within the knowledge triangle framework, global requirements in self-directed learning and development of competences, or in trans-disciplinary applications onto real-life situations, are addressed. The short range outputs consider structural aspects, collaborative development and innovative practice, while the long range outcome is to foster regional sustainable development.

The European networks such as GAST, ERABEE-TN, or 3LENSUS are requiring large consortia, usually more than twenty partners with relevant impact at European and international level: vocational institutions, higher education institutions, research centres, and local/regional/European stakeholders. However, the minimum number of European partner countries in the Erasmus/EACEA consortia is usually (but not in all subprograms) three EU partner countries.

The partnership in EURO-QLIO-Filière Euro Qualité Logistique des Organisations integrate only three partners from different EU countries (France, Romania, and Bulgaria) that developed and implemented a virtual bachelor/

master course for the study of quality, industrial logistics and organization. The multimedia modules are based in a distance study platform, distance teaching and tutoring methodologies are applied, and group sessions for additional training, discussion, and assessment are prepared. A pool of industrial contacts is developed, the transference of know-how and tools to the companies is promoted through the placement of trainees, and this way companies' performance and competitiveness is expected to be enhanced at European level.

However the MSc. curriculum project LSCM-Logistics and Supply Chain Management integrated six different partner countries in the partnership. The main objectives of this European project for curriculum development in Logistics and SCM were the definition of an innovative program aiming at the efficiency and competitiveness of companies, responding to the education needs of the SC labor market, fostering staff mobility and providing an European dimension for the program, involving the professional SC sector, bodies and associations, and achieving accreditation of the two years program.

Similarly, the project RIFLE-Rail Freight and Logistics Curriculum Development integrated nine different partners in the partnership, also to develop curricula and modules for a MSc. program on the field.

The Erasmus project Odss.4SC-Optimization and Decision Support Systems for Supply Chain also addresses MSc/PhD studies, developing and implementing an intensive program on Optimization techniques directed to industry-based SC and to integrate well-known DSS. The modeling and optimization of a network of production-distribution facilities are focused, considering the material and financial fluxes in a multi-echelon framework, and also addressing the green logistics approach. The technical sessions follow a pull strategy, beginning with distribution/sales/customer subjects, and ending with the selection of suppliers. In-between, both the planning/scheduling of the production processes and the supporting systems usually found in manufacturing, petrochemical, and pharmaceutical SC are addressed. The reverse logistics is also treated, technical visits to industry-based SC are foreseen, and the computational sessions are supported by IBM/ILOG.

Important points of the Odss.4SC program are the promotion of mobility of MSc/PhD students and teachers, the discussion between Optimization researchers and SC practitioners, and the stimulation of new ideas among industry participants. This is specifically relevant for the construction of the European Higher Education area, due to the diversity of mother-languages and the cultural differences in Europe.

Notwithstanding, there are also opposite approaches where attendance follows a virtual mode, contents are delivered by ICT tools and free of charge: the Massive Open Online Courses (MOOC). The MOOC concept is gaining space, first in North America areas, then in Europe and other countries. The MOOC approach is particularly interesting in large countries where the distance learning is a most, and assuming their ICT structure may support contents deliverance and large fluxes of data. The number of available MOOC is continuously increasing but we refer, for instance, the Logistics and SCM open course that surveys Operations Research models and techniques related with Logistics and SC fields.

Beyond education international programs, also the research cooperation projects are following the knowledge triangle's guidelines. Targeting efficiency on resources utilization and global competitiveness for European companies, a set of funding schemes is implemented on behalf of the 7FP-7th Framework Programme. Some of the subprograms within 7FP are considering specific fields, for instance, Transport, Energy, International Cooperation, but addressing the sustainable development and the economic growth as transversal priorities.

The cooperation project MAREX - Exploring Marine Resources for Bioactive Compounds: From Discovery to Sustainable Production and Industrial Applications is expected to provide new marine-based compounds for European industries and develop their product mix related to pharmaceutical, cosmetic, agrochemical, food processing, among others. Based in better understanding, biodiversity and environmental concerns, the aim is to develop marine biotechnology products and foster European productivity in the field. The main activities were focusing the organic synthesis of certain active compounds and their derivatives, in a way to provide sustainable sources for the industrial sectors referred in above.

In the same perspective, the Erasmus thematic network Aqua-tnet- Promoting Innovation and a European dimension through Lifelong learning in the field of Aquaculture, Fisheries and Aquatic Resources Management is targeting marine and aquatic resources, through multidisciplinary collaboration of more than eighty partners, including universities, vocational institutions, research centers, industry associations and other relevant field players.

The project SUSTAINMED-Sustainable agri-food systems and rural development in the Mediterranean partner countries (MPC) is expected to promote the EU competitiveness in international markets, by improving the economic and commercial relations with the partner countries from the Mediterranean area. It was thus necessary to analyze the impacts of European and MPCs national policies in the agricultural, rural, environmental and trade sectors. The main activities integrated complementary methods and analytical tools such as quantitative modeling, structured surveying, indicator building and qualitative data analysis.

With a similar perspective, the project OLITREVA-Capacity Building for Sustainable Treatment and Valorisation of Olive Mill Waste (OMW) in Palestine intends to avoid the landscape deterioration and the pollution of groundwater, soil, and surface, and in special the high consumption of water resources by olive mills. The crucial tasks are related to find effective treatment methods for OMW generated by the olive industry, which is an important sector for the Palestinian agricultural income. The development of local capabilities in cooperation, research, and technology is a key task, in a manner to support the various small-scale projects that have been carried out.

By other point of view, the project MYCORED-Novel integrated strategies for worldwide mycotoxin reduction in the food and feed chains applied new methodologies, efficient handling procedures, predictive modeling and optimized logistics, and educational strategies to reduce mycotoxins exposure worldwide. The contamination by mycotoxins is a major concern in food and feed chains, namely in wheat, maize, grape-wine, and dried fruit chains. Beyond the contamination reduction procedures, the involvement of universities and research centers from the five continents allow to share experiences and good practices in a global context.

The security of food and feed chains is also the key subject of the project FOSRIN-Food security through ricebean research in India and Nepal, since ricebean is a legume that presents a large potential for improvement. Ricebean produces large amounts of fodder and grain, it grows well then the main objective is to disseminate ricebean. The target is to model the food SC, by carefully analyzing high transaction costs, weak information links, identifying the agents fostering/opposing ricebean introduction, and finally aiming at the ricebean consumption. A very complete set of activities (molecular markers, mother trials, baby trials, statistical and dietary data, and food preparation) is having a positive impact on farmers' livelihoods and food security.

Food safety also is the main concern of the project VEG-i-TRADE-Impact of climate change and globalisation on safety of fresh produce — governing a supply chain of uncompromised food sovereignty, due to several disease outbreaks and alerts attributed to fresh produce. Food safety in VEG-i-TRADE is addressing microbiological and chemical hazards, bringing together more than twenty partners (universities, research centres, and industrial partners), applying analytical testing methods and risk assessment, and developing management strategies in the fresh produce SC.

CONCLUSIONS

Throughout this chapter, the main characteristics of relevant international education programs and cooperation projects on green logistics and agro-industries were presented, and review articles on RL were analyzed and listed.

Our approach followed the guidelines of the knowledge triangle, which supposes the construction of the knowledge-based economy with support on higher education, research results, and innovative practice. The long range outcome is the global competitiveness of the European economy, its sustainable growth and the efficient utilization of scarce resources.

The main purpose of this study was to identify the topics in the field of green logistics and reverse logistics that have been investigated, allowing the knowledge of their current state in order to detect possible gaps, to note future directions of research in these areas, and to allow some insights to be developed in the near future.

From the articles analyzed and in concordance with the results obtained, it can be considered that the green logistics concept, although recent, has aroused the interest of researchers. Thus, some considerations are presented:

1. Many of the references are general, short and practice-oriented, and do not provide a sound analysis and integration of green logistics topics; in plus, it is considered necessary an interdisciplinary field to remove distances in the green logistics research;
2. Few authors have holistically dealt with the reverse logistics' concept, most research was exploratory, and there is a lack of theories ground. For practitioners, the design and improvement of management and reverse

logistics networks could be facilitated by the presence of a reference model;

3. Future research should be directed to the theory for strategic analysis and organizational development, establishing a framework in which the tactical and operational aspects can be developed upon;
4. From the product 's design phase onto the final consumer, the reverse logistics' concept should be explored and integrated as a viable option in the life cycle of the product;
5. Research should build links between the steps that managers can take to reduce the gap between customer expectations and service quality perceived in reverse SC;
6. The development of pricing models for products is needed, to be used in concordance with the life cycle of the product and with the various levels of quality.

From the international education programs and cooperation projects that are analyzed, some comments are presented:

1. While the number of partners in the consortia vary largely with the type of program/project, from the minimum of three partners until more than eighty, the relevance and the complementarity of expertise are key factors;
2. The dissemination and exploitation of the program/project results are important factors too, for instance, considering the utilization of ICT tools, the development of virtual courses, or even the freely deliverance of big data within MOOC;
3. Beyond the ICT evolution, agro-industry SC shall consider tools for mobile applications, allowing real time decision making, treatment of customer issues, and implementation of agent-based systems;
4. The curriculum development in green logistics must directly consider the requirements of companies in the field, the enrolment of trainees, internships, and the impact on competitiveness and productivity;
5. The economic priorities, environmental rules, and food security issues play an important role in the design and implementation of agro-industry SC;
6. Notwithstanding the specificities of each type of crop or agro-product, there are similarities in the optimization of the agro-industry business, the aquaculture and marine production, or the forestry management, being convenient to share common modeling and solution procedures.

Thus, green and reverse logistics still is a field fertile for research and application, and it has been deepened in different ways and at different levels in various categories. Green logistics is a theme that spans many scientific fields and requires further research, being this chapter a contribution to the design of future research.

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CHAPTER 7

COLLABORATION & KNOWLEDGE MANAGEMENT: AN INTEGRATIVE MODEL TO COMPREHENSIVELY ASSESS GREEN COLLABORATION IN SUPPLY CHAIN NETWORKS

Carlos Meisel
Helmut Zsifkovits
Chair of Industrial Logistics, University of Leoben (Austria)

INTRODUCTION

The pace of change and the uncertainty about the evolution of the markets coupled with revolutionary advances in communication and information technology has led to new and more competitive, unstable and complex environments. To survive in this environment, companies have not only to be aware of the supply chain they are members of but also to understand the roles they play.

Owing to this new business scenario, process management within a company and along the supply chain is now evolving from a traditional and vertical functional management system to a matrix arrangement of highly integrated processes (Hammer and Stanton, 1999). This new arrangement is looking to promote greater integration, visibility and collaboration both across functional departments within an organization and between multiple trading partners along the supply chain. In other words, this new approach is looking to engage companies along the supply chain into an ongoing and long-term relationship allowing the flow of knowledge across the network with the aim of bringing mutual benefits to all collaborating partners involved as well as an increasing customer service level.

LITERATURE REVIEW

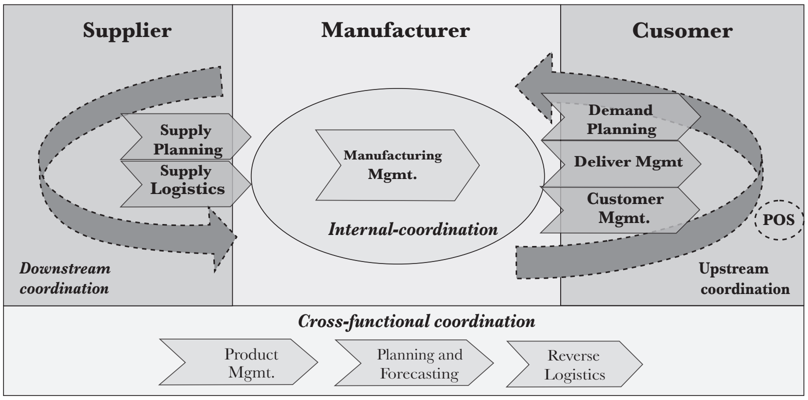
The Council of Supply Chain Management Professionals (CSCMP) has defined Supply Chain Management as the planning and management of all activities involved in sourcing and procurement, conversion, and logistics management activities. Special remarks are given to coordination and collaboration relationships with supply chain partners, which can be suppliers, intermediaries, third party service providers, retailers and customers to facilitate integration of supply and demand management within and across companies.

Ballou (2007) identified three different levels in SCM, namely: logistics operations, inter-functional coordination, and inter-organizational coordination (see figure 1). Logistics operations includes managing activities and processes such as planning, procurement, material flow management, operations, inventory management, transportation, warehousing, distribution, customer service and the information systems used to monitor

these activities. Inter-functional coordination refers to a horizontal business function focused on building collaborative relationships with other functional areas (functional business units) in the same firm. Inter-organizational coordination has to do with collaborating and coordinating products flow among (forward and backward) supply chain trading partners.

Mentzer et al. (2001) are portraying SCM as a strategic level concept, considering SCM to be "the systemic, strategic coordination of the traditional business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole". Lambert et al. (1998) understand a Supply Chain in terms of relevant business processes, penetrating both functional silos within the company and various corporate silos across the upstream and downstream activities of the supply chain. These processes interact throughout the different supply channel members for the purpose of adding value for end consumers and stakeholders.

Figure 7.1: Scope of Supply Chain Management.



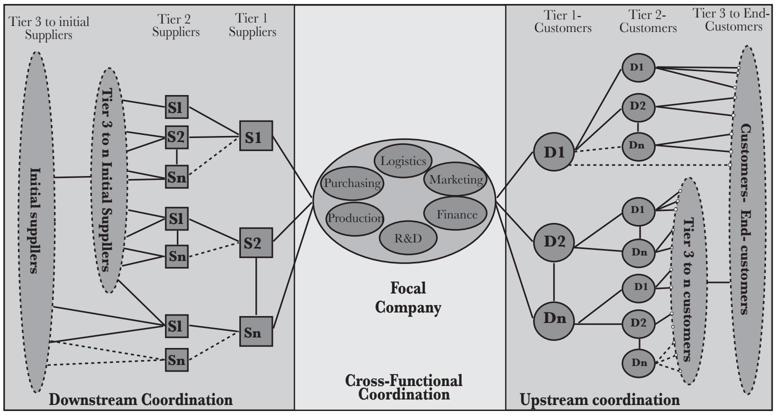
Source: Based on Gruat La Forme et al (2007)

In the last decades, changes in the business environment have contributed to the development of supply chain networks. Thus, some actors have viewed supply chain management as an inter-organizational Supply Chain Network (SCN) of autonomous or semi-autonomous business entities involved, through upstream, cross-functional and downstream links, in the relevant business process that work together to design, produce, deliver goods or services to the end customers (see figure 7.2). In other words, SCM is the management of the integral network of interconnected business processes relevant by keeping the oversight of materials, information, and finances as they move in a process from supplier to manufacturer to wholesaler to retailer to consumer. It involves coordinating and integrating flows within and among companies (Lambert et al., 1998).

Numerous articles published in the literature research and Supply Chain Management practices provide a basic rationale to identify collaborative initiatives along the supply chain as essential factor of managing supply chains. It involves the issues of how to build both across functional departments within an organization and between multiple Supply Chains trading partners multiple inter- and intra-organizational relationships.

The term collaboration in the Supply Chain context has been discussed as a way of working that encompasses all supply chain partners, coordinating specific activities and exchanging of appropriate information to leverage resources having the purpose to seek the objectives among counterparts. Put another way, collaboration brings the possibility of accessing hard and soft issues (resources, knowledge, relationships) others have and using each party's resources for mutual benefit (Shuman and Twombly, 2010). Furthermore, collaborative partnerships can lead developments in information systems technology and better data and information transfer can results in the development of new capabilities or in the sharing of complementary knowledge between and among partner members (Trim and Lee, 2008). It requires an environment of trust, reciprocity, flexibility, interdependence and commitment (Vieira et al., 2009).

Figure 7.2: Generic Structure of a Supply Chain Network.



Source: Based on Lambert, Cooper und Pagh (1998)

Thus, in addition to the possibilities for the trading partner to added value for end consumers and stakeholders through collaborative relationships, nowadays collaboration throughout the supply chain also has a focus on knowledge perspectives such as sharing, swapping, and integrating knowledge to overcome barriers in pursuit of common goals (Carayannis, 2000). Organizations should disseminate and embody new knowledge beyond the organizational boundaries, leading to increased collaborative partnership and alliances by close relationships with the supply chain members (Nonaka and Takeuchi, 1995). Rogers (1996) argues that the fifth generation of R&D management is collaboration. He also asserts that companies should work in collaborative systems with suppliers, corporate partners, distributors, and others to enable the flow of knowledge (information with meaning) throughout the supply chain. Findings of Yli-Renko et al. (2002), support the hypothesis that the higher levels of interaction between the members within an organization as well as among external channel partners correlate to a higher accumulation of knowledge.

It can be pointed out that companies seeking to improve their competitiveness should engage in the development of sustainable collaborative partnerships. For instance, Albino et al. (2012), claim that inter-organizational collaborative relationships have a significant effect on firms' environmental performance. Indeed, Lacy et al. (2010), highlight the key role of collaborative relationships to face environmental challenges, which likely require the integration of diverse knowledge coming from diverse organizations e.g. environmental collaboration with government, NGOs, customers and suppliers, other organizations, and universities and research institutions.

The recognition that inter-organizational relationships as a core element of the supply chain management from satisfying end-customer and stakeholders has triggered research on the factors that enable the development of effective partner relationship. In other words, on the factors that make a collaborative relationship successful. More in-depth, there are results interesting to know about both the characteristics of the interaction among the channel partners and the coordination conditions and trade-offs that may exist among the business processes and activities throughout a value chain of multiple companies.

In this context, Aryee and Naim (2008) stated that the contributory factors to enable supply chain integration can be split in two dimensions, "hard" issues, such as technology and "soft" issues such as initiative of collaboration. These issues allow companies and even a network of organizations to enhance the process coordination and collaboration both across functional departments within an organization and between multiple partners along the supply chain.

Additionally, in the search for performance improvements several approaches have been investigated to enhance collaborative relationships within organizations and among supply chain partners as a catalyst for the evolution of a variety of collaborative planning initiatives. Judging by the "soft" issues which were referred above, three different collaborations initiatives can be selected: Firstly, maturity models which have been proposed as an attempt to address the extent to which enterprise or supply chain business process for recurring collaboration practices are designed, measured, improved and managed, with the objective of creating sustained collaboration practices (Lockamy and McCormack, 2004). In this way, processes are now viewed as assets that must be developed until they reach an advanced maturity level and maturity models as a means that can be used to help facilitate enhanced process maturity. Secondly, supply chain collaboration efforts such as Efficient Consumer Response (ECR), Continuous Replenishment (CR) and Collaborative Planning Forecasting and Replenishment (CPFR) which have been proposed as strategies to manage a process integration, visibility and collaboration. In other words, these tighter initiatives aims at the driving need to develop an on-going and long-term trust-based relationship from suppliers' supplier to customers' customer, with the sharing of strategic information and process integration in order to fulfil consumer wishes, better, faster and bring mutual benefits to all supply chain partners in the form of reduced inventory and cost (Barratt and Oliveira, 2001).Thirdly, process reference models (PRM), which have been proposed as performance frameworks dealing with the way to describe and communicate processes, tune them, measure and control process performance and implement processes more efficiently both upstream and downstream the supply chain.

Gruat La Forme et al. (2007) have identified two main dimensions that are commonly considered in many different studies concerning the collaborative relationships among the supply chain partners. On one hand, some studies deal with the extent of the collaboration, as the perimeter to which collaboration activities are spread throughout the supply chain. On the other hand, other works deal with the intensity/depth of the relationship, as the degree or measure of closeness or strength of the relationship among partners in collaboration, from single information sharing to real partnership (Golicic, et al., 2003).

Kanter (1994) categorizes five levels of integration that are influential on successful collaborative relationships among partners in a supply chain. At strategic integration, through the continuing interactions among the top leaders, broad goals and changes in each company are achieved. At tactical integration, there are middle manager working together on specific projects or joint activities looking for instance to link the companies better or to enable knowledge flow among the supply chain partners. Interpersonal integration is a means to develop synergies born in paper. Thus, relationships between companies are more than integration of functional areas in pursuit of common goals. People in a collaborative relationship play a strong role, that is, they need to know each other before to be willing to make efforts together. By operational integration is referred to the rules that allow people to carry out the day-to-day work. Finally, cultural integration, allows both sides to establish cultural awareness.

Building on the work of Kanter (1994) and Vieira et al. (2009), collaborative attributes to enable inter-organizational relationships among the supply chain, in this endeavor are categorized into three types of factors:

- strategic;
- tactical; and
- interpersonal.

These later are discussed in detail, as they form the basis for the model discussed in this contribution.

BUILDING THE FRAMEWORK FOR GREEN SUPPLY CHAIN COLLABORATION (GSCC)

GSCC is addressing coordination and collaboration relationships in a supply chain, with focus on jointly achieving improvements in terms of resource and energy utilization, for the benefit of the partners involved and the environment.

Attributes to Enable Collaborative Relationships

Based on a comprehensive literature review, the attributes to enable GSCC were collected and classified within the three factors identified above. A stream of literature supports the value of the attributes below mentioned. Indeed, their presence strengthens the probability of success of a collaborative relationship and their absence in many cases increase the change of failure.

Strategic Relationships

Strategic relationships perspective is an integral part of the goals of the firms in an inter-organizational relationship. Firms that are unwilling to articulate their strategies probably would be unable to build a closer relationship. This factor includes the following attributes: Selecting an environmental partner, strategy congruence, relationship history, and top management involvement.

Selecting an environmental partner
This attribute refers to the knowledge that one company should have about its collaborative partner before committing to a green alliance. This includes knowledge other expertise in specific areas that can provide to pursue specific goals. When the collaborative partnership is planned with a NGO, this group should have a recognized, credible reputation. Selecting the right partner to begin with is just the beginning, but an important success factor to take into account (Hartman and Stafford, 1997).

Organizational congruence
Organizational congruence reflects the degree to which the corporate, business and functional strategies of the firms in partnership are mutually compatible and consistent. The better aligned the goals and objectives of the trading partners are, the greater the willingness of them to building a closer relationship and the higher the chance of collaborative relationship success are (Lambert et al., 1996; Golicic and Mentzer, 2005). Compatible organizational culture also helps to build effective long-term inter-firm dyadic relationships (Paulraj et al., 2008).

Relationship history
There is support for relationship history as a strategic relationship driver in the literature; it has been assumed that both good prior relationship experience (Lambert and Knemeyer, 2004) and the age of the relationship may guide enterprises to establish close relationships (Golicic and Mentzer, 2005). This attribute can be measured by the degree of prior formal associations between two organizations, ranging from few relationships to many relationships.

Top management involvement
Drawing on the conceptualization of top management involvement as an attribute on the strategic relationship level, Kanter (1994) emphasizes that it is essential that top management gets involved into the collaborative agreements since stakeholders will set business rules to enable compatibility between the partners in collaboration. Furthermore, top management support plays an essential role in communicating the shared vision and implementing strategic decisions within an organization, as well as by deploying necessary resources, facilitating the development of strategic relationships with key supply chain partners (Mentzer et al., 2000).

Tactical Relationships

The tactical relationship perspective is concerned with bringing managers together to align the individual goals with the joint goals, to come with more efficient connections and to guide a better knowledge exchange between partner business processes (Kanter, 1994). This factor includes: joint actions; cost, risk and reward sharing; information sharing structure and resource sharing structure.

Joint actions
This element outlines the degree with which supply chain partners work together pursuing individual or collective common goals. In other words, the extents to which channel partners undertake activities jointly rather than unilaterally (Heide and John, 1990). Min et al., (2005) found that joint efforts such as planning, goals setting, performance measurements, and problem solving, are essential for successful collaborative relationships. Moreover, the creation of cross-functional supply chain teams with members from both companies to carry out focused activities, aiming to design integrated processes

that built and sustain the partnership (Vanpoucke and Vereecke, 2007). Furthermore, several studies suggest that joint efforts enable partners in cooperation to co-align their operations and processes, which enhances the relationship by building trust and commitment (Min et al., 2005; Jap and Ganesan, 2000; Subramani and Venkatraman, 2003).

Cost, risk and reward sharing
This attribute refers not only to the benefits and rewards of partnership, but also to the cost and risks shared by partners. Lambert et al call this element “shared destiny” (Lamber et al., 1996).

Communication and information sharing
Effective communication and information sharing on a frequent, bidirectional, informal and non-coercive basis is an essential component of successful green collaborative relationships (Mohr and Spekman, 1994), Mohr et al., 1996). Communication links should be within all levels of the organizations as well as across the supply chain trading members. Sharing information in an effective way is essential, both to guarantee joint actions and also for partners who may use it to improve their business process (Min et al., 2005), more over is a critical factor for partners to realize benefits of collaboration (Vieira et al., 2009). This attribute is defined as the reliability, completeness, exactness, timeliness and appropriateness to which critical, often proprietary information of appropriate relevance is communicated between supply chain partner through media such as face-to face meetings, telephone, fax, mail and the internet (Vanpoucke and Vereecke, 2007).

Resource sharing structure
Since there are other resources (more than information) to be leveraged within the context of green supply chain collaboration (Xu, 2006), this dimension is extended to include all of these resources, such as assets, knowledge, inventories and relationships other people and organizations have and using each party’s resources for mutual benefit. This variable is measured by the degree to which participants’ resources are leveraged for the benefit of all parties.

Interpersonal Relationships

Interpersonal relationships are necessary to develop in practice all the synergies born at strategic level. Relationships not only involve the integration of functional areas in seeking to achieve common objectives, but also involve the employees that work for the firms, their own personalities, emotions and the willingness to change (Golicic and Mentzer, 2005). People are not willing to exchange information, technology or participate in joint teams until they know one another personally. Published attributes directly related to this factor are: trust, interdependence, mutuality, and commitment.

Trust

For the purpose of the current endeavour, inter-firm trust is conceptualized as the willingness to belief that the partner can be relied on to fulfil obligations, behaves in a predictable manner and in its behaviour is honest and ethic even when the possibility for opportunism exists (Zaheer et al., 1998). Geyskens et al. (1996) argues that the higher a firm's trust in its partners, the higher its motivation to continue the collaborative relationship. That is, trust is presented as the cornerstone of the partnership, because relationships characterized by trust, will enhance the parties' desire to commit themselves to such relationships (Hrebiniak, 1990). Successful collaborative relationships can be supported by maintaining and enhancing high level of trust (Nyaga et al., 2008; Cai et al., 2010). For some authors in the literature, trust encompasses three essential elements - trust in the partner's benevolence, honesty and credibility (Moorman et al., 1992; Morgan and Hunt, 1994). Likewise Ganesan (1994) has suggested that partners who trust each other will be more satisfied with the relationship and will be more willing to put additional efforts ensuring it continuity. Additionally, those trusting partners will commit resources to the relationships, because the relationship is perceived as a long term investment.

Interdependence

Interdependence or mutual dependency measures the level to which trading partners work together to obtain mutual benefits, since each partner are relatively equally dependent upon the other's knowledge (Mohr and Spekman, 1994). Heide (1994) defines two types of organizational interdependence: level of interdependence and preference structure. Furthermore, he presents two dimensions to describe levels of interdependence: symmetric versus asymmetric and cooperative versus competitive. Duffy found empirical evidence that supports interdependence as an essential attribute in distinguishing partnerships from other kind of relationships, the type of partnering strategy employed and the extent of collaboration achieved (Duffy, 2008).

Mutuality

Collaborative relationship has to bring mutual benefits for the trading partners (Ellram and Edis, 1996). According to Holmlund and Törnroos (1997), mutuality is described by four core features: the degree of mutuality that dominate the relationship, the multitude of different bonds- technical, economical, social, knowledge and legal - between the partners, the symmetrical nature of the relationship (e.g. importance of each partner to the other's success, relative size, market share, financial strength, productivity, brand image, company reputation and level of technological sophistication), and the balance achieved in the long run. These characteristics bring sustainability to the relationship even in situations with low mutuality. Deep one-sided asymmetry in the relationship may cause loss of interest from the other partner in maintaining and developing the relationship (Häkansson and Snehota, 1995).

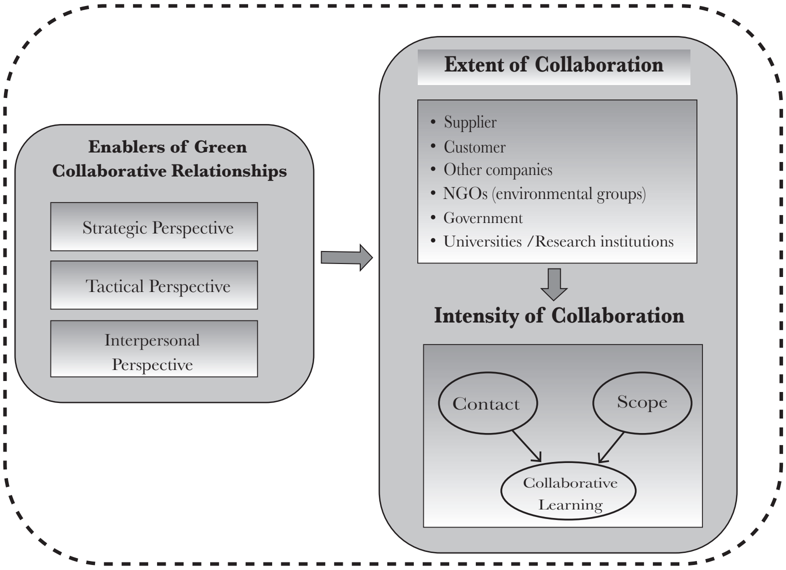
Commitment

Finally, commitment has been defined as the enduring desire of the supply chain partners to maintain a valued on-going relationship, which may occur in the form of an organization's time, money, resources, etc. According to Morgan and Hunt (1994) the committed partners believe the relationship is worth working and for that reason they want the collaborative relationships to persist and they will be willing to exert efforts on behalf of the relationship. Prahinski and Benton found that committed partners often achieve positive impact on performance (Prahinskik and Benton, 2004), while Krause et al reinforce that performance improvements are often made possible when partners commit to long-term relationships (Krause et al., 2007).

GREEN COLLABORATION CHARACTERIZATION MODEL (GCCM)

Concerned with understanding the partnership relationships between the supply chain members and the feature of the associated ties between them, this paper proposes the GSCM matching the contributory factors to enable GSCC against the two dimensions mentioned by Gruat La Forme et al, the intensity of the collaboration dimension, and the extent of collaboration dimension (see figure 7.3). The main idea of this model is test the influence of the attributes to enable GSCC into the collaboration characterization. Hence the following hypothesis will be tested: higher levels in the attributes to enable supply chain collaboration increase the extent of collaboration as well as the intensity of collaboration.

Figure 7.3: Structure of the GCC Model



Source: Research Model

INTENSITY OF COLLABORATION DIMENSION

The collaboration intensity/depth of collaboration in this work is referred as the frequency of contact between exchange partners, the scope of collaboration and the degree to which the partners learn through collaboration.

The frequency of contact outlines the number of interactions *between* exchange *partners*. In terms of the intensity of collaboration, it will be measured by the reported frequency of contact, and ranging from no contact, to yearly, quarterly, monthly, weekly, and daily. One of the hypotheses to prove by means of an empirical study is: the greater the frequency of contact, the higher the probability/depth of collaboration, and the more information and learning is passed between the parties.

The scope of collaboration is an assessment of how the range of collaboration between the partners is. In other words, describe the current relationship between the organizations along the supply chain and is defined by the degree to which activities are coordinated, from single information sharing to real partnership including the sharing of vital information. Scope ranges from *unlinked* (do not work together at all), to *communication* (share information only and usually during the exchange of products or services), *cooperation* (work together as an informal group to achieve common goals), *collaboration* (work together as a formal team to achieve common goals), *partnership* (work together as a tailored business relationship based on mutual trust, openness, shared risk and reward that return a competitive advantage), and joint ventures (normally entail some degree of shared ownership across the two parties) (Lambert et al., 1996). The hypothesis hence is: the greater the scope of collaboration, the more information and learning is passed between the parties.

Collaborative learning seeks to measure the degree at which the supply chain partners capture, share and utilize learning, knowledge, and insights from counterparts through the relationships itself.

Extent of Collaboration Dimension:

Using the grounded theory approach depicted by Albino et al, this work describes the extent of collaboration dimension as any collaborative relationship undertaken with six categories of actors (suppliers, customers, other companies, NGOs, government, and universities and research institutions) along the supply chain aimed to reduce the supply chain environment impact. The specific aim here is thus to reinforce the hypothesis tested by Albino et al. (2012) is thus to investigate whether collaboration with different types of actors and also at different levels of collaboration intensity, have impact on both companies' environmental and business performance. Also this attribute will be addressed from a dyadic relationship between two members to an integrated relationship including all partners above referred (see Table 7.1).

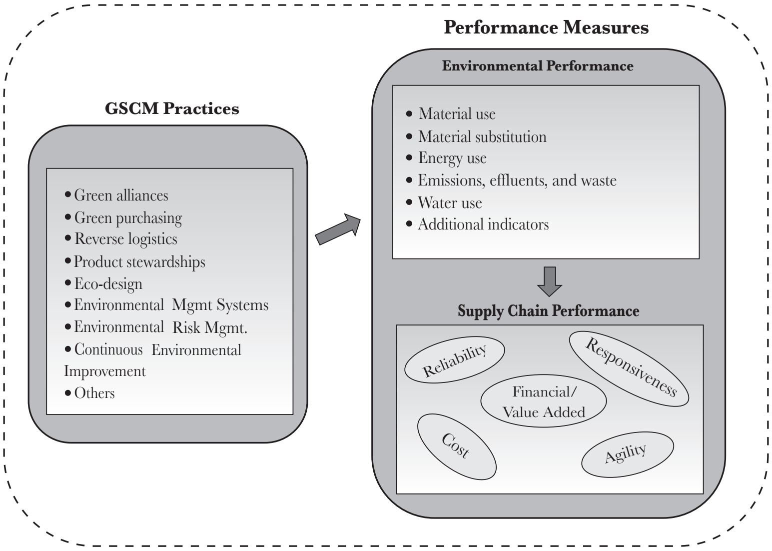
Table 7.1: Possible Green Collaboration with Different Types of Actors

Environmental Collaboration with	Description	Hypothesis tested in the literature
Suppliers or customers	Direct engagement of a focal company with its suppliers or customers	Environmental collaboration with suppliers/customers has both a positive effect on environmental performance as well as on business performance (Roy and Wheland, 1992; Hall, 2000, Zhu and Sarkis, 2004, Vachon and Klassen, 2008).
Other companies (horizontal collaboration)	Engagement with companies either of the same supply chain stage, or even with companies belonging to different supply chains	Environmental collaboration with companies other than suppliers and customers has a positive effect on environmental performance (Albino et al., 2012).
NGOs	Engagement with environmental NGOs	Environmental collaboration with NGOs has a positive effect on both environmental performances as well as on a higher business performance (Stafford et al., 2000; Rodinelli and London, 2003).
Government	Engagement with either with the central government, local government, or government agencies	Environmental collaboration with government has a positive effect on environmental performance (Roy and Wheland, 1992; Hart,1995).
Universities and research institutions	Engagement between industrial firms and universities and research institutions	Environmental collaboration with universities and research institutions has a positive effect on environmental performance (Noci and Verganti, 1999; Foster and Green, 2000; Seuring, 2004).

GREEN COLLABORATION PERFORMANCE MODEL (GCP MODEL)

Grounded on the work done by Young et al. (2012), this work proposes the GCP model. This framework is suggested as a way to evaluate the positive link found between the Green Supply Chain Management (GSCM) Practices and both environmental performance outcomes as well as supply chain business performance measures (See Figure 7.4).

Figure 7.4 Structure of the GCP Model



Source: Research model, based on the model proposed by Youn et al. (2011)

The primary goal of the GCPM model is thus to evaluate whether organizations are using GSCM practices under a collaborative approach, to assess and mitigate their impact on the environment. Put another way GSCM practices may help companies to improve their environmental performance (see Table 7.2).

As successful implementation of the GSCM practices may allow organizations to reap other benefits such us improved organizational reputation, increased market penetration and better operational performance (Zhu and Sarkis, 2004). The proposed model suggests both the direct impact of GSCM practices on companies' environmental performance and indirect impact of GSCM (through environmental performance improvements) on supply chain business performance (see Table 7.2).

Table 7.2 Different GSCM Practices and their Impact on environmental and Business Performance

<table>
<tr><th>GSCM Practice</th><th>Description</th><th>Environmental / Business Outputs</th></tr>
<tr><td>Green Purchasing</td><td>The purchasing function and its close collaboration with suppliers focused in procurement of environmentally friendly raw materials and in the developing of products that are environmentally sustainable (Zhu et al., 2008)</td><td>May allow for significant reductions in waste and improvement in product disposal procedures (Youn et al., 2011).</td></tr>
<tr><td>Eco-design</td><td>Eco-design is focused on the design of products that minimize the consumption of materials and energy, that avoids or reduces the use of hazardous products during the manufacturing process, and that facilitate the reuse, recycle or recovery of components materials and parts (Zhu et al. 2008).</td><td>Reduce potentially harmful environmental effects during the whole product's life cycle e.g. from product design to material disposal (Hart, 1995; Sroufe, 2003; Montabon et al., 2007).</td></tr>
<tr><td>Environmental Management Systems (EMS)</td><td>To help manage environmental sustainability as a strategic organizational imperative and also to measure environmental performance on an ongoing basis, some organizations have adopted EMS such us ISO 14001 or Eco-Management and Audit Scheme (EMAS), or they promote their own in-house environmental system (Shaw et al., 2010)</td><td>Commonly may lead companies to achieve better environmental performance. However the evidence that EMS leads to a better business performance is not very strong (Maier and Vanstone, 2005). In addition, companies that implement an EMS, are more like to evaluate their suppliers' environmental performance as well as more likely to encourage their suppliers to adopt specific environmental practices (Arimura et al., 2011).</td></tr>
<tr><td>Environmental Risk Management</td><td>A proactive approach for identifying, quantifying and controlling company's environmental risks.</td><td rowspan="2">Allow companies to gather long-term benefits due to the proactive focus of these practices; these benefits include an improved company's public image, increased market share and improved environmental and business performance (Youn et al., 2011).</td></tr>
<tr><td>Continuous Environmental Improvement</td><td>Implementation of environmental-friendly practices such as in design, manufacturing….. as well practices such as waste reductions, recycling, reuse and material substitutions</td></tr>
<tr><td>Green Information Systems</td><td>Information systems that are focused on monitoring environmental practices and outcomes</td><td>Green Information System have a direct impact on environmental collaboration with suppliers and as well as with customers. Both positively impact environmental performance which, in turn, directly impact organizational performance (Green et al., 2012).</td></tr>
<tr><td>Other ESCM Practices</td><td>Any other practices used by companies and not mentioned above.</td><td></td></tr>
</table>

Traditionally, supply chain performance systems have been oriented around cost, time and quality. However, over the last years, with organizations facing increasing scrutiny from customer, government and society regarding their observance of environmental regulations and social responsibility, it is a necessity for organizations to begin quantifying their impact on the environment. Based on this trend, the second part of this GCPM framework is built on two types of indicators, i.e. environmental supply chain performance (ESCP) indicators and business supply chain performance (BSCP) indicators. Indeed, this model is aiming to introduce environmental performance measures into the well-known and existing bank of supply chain performance measures.

Adapted from the Global Reporting Initiative (2012), a set of six ESCP measures is shown in Figure 7.4: material use (i.e. material wasted, recycled, reused, waste reduction); material substitution; energy use (i.e. consumption, energy saved and initiatives to provide energy efficient); emissions, effluents, and waste (to air, to water, to land); water use, recycled and reused; and additional indicators (i.e. use of renewable energy, impacts of transportation used for logistical purposes among others).

Finally for the business performance indicators, and based on the performance attributes described in the SCOR model, a set of five metrics will be used to measure the supply chain performance (see Figure 4).

CONCLUSIONS

Collaborative linkages both within the functional departments and across external organizations have taken on an increasing level of importance. Successful SCM nowadays requires a change of paradigm from managing individual functions to integrating activities into key supply chain processes involving collaborative work between supply chain members.
So, supply chain members should work together at all levels of integration (strategic, tactical and interpersonal) to create a competitive advantage through the sharing of information, cost, resources, decision-making, risk and reward between two or more parties. This collaborative relationship may result in greater profitability from satisfying end customer needs than the firms could achieve on their own.

In order to move forward collaborative relationship, a framework built on existing research theory and practice to characterize green collaborative relationships and to assess the ability of the supply chain members to work collaboratively is depicted. This framework is based on two models: a GCC model and a GCP model.

The GCC model constitutes a practical tool that can be used to evaluate the positive link between the contributory factors and the two dimensions of collaboration characterization as well as to evaluate the ability of the green partners in collaboration to create knowledge. Put another way, this model should allow companies to assess both the ability of the green supply chain members to work in a collaborative way and the capability to exchange and create knowledge throughout this collaborative relationships. As a collateral result of this model, the attributes to enable GSCC are gathered and classified into three categories: strategic, tactical and interpersonal factors.

On the other side, the GCP model presented here should permit companies to evaluate the impacts of their ESCM practices, both on their environmental performance outcomes and on their supply chain performance outcomes.

Further steps in this research are going to deal with a questionnaire design and the application of an empirical case study to validate both the postulates and the model here developed. The green collaborative relationship between the supply chain members and the feature of the associated ties between them through a social network analysis will be evaluated. In order to do that, structural variables such as linkages between a pair of actors (relationship), extent of collaboration, intensity of relationship, the scope of the relationship, and the extent of collaborative learning will be used. Further, prior to the main survey and by means of a pilot survey the first results will be gathered and the framework presented here will be instanced and validated.

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CHAPTER 8

GREENHOUSE GASES EMISSIONS IN THE SUPPLY CHAINS: COLOMBIAN BIOFUELS CASE

Monica Julieth Valencia Botero
Angela Andrea González Villa
Carlos Ariel Cardona Alzate

Universidad Nacional de Colombia Sede Manizales

INTRODUCTION

Social, economic, political and environmental crisis associated to fuels is a known-fact (Demirbas, 2009; Larson, 2006; Zidansek et al., 2009). Conventional sources (fossil fuels) have generated important Greenhouse Gases emissions (GHG) amounts, which have been related to climate change and global warming (Davis et al., 2009; Guinée et al., 2009; von Blottnitz et al., 2007). Additionally, the development processes are related to several energy sources availability.

During last decades, the studies have been addressed to find other fuels, including other fossil fuels (carbon, natural gas), gasoline additives (MTBE, ETBE, TAME, DIPE) and other biomass-based fuels (bioethanol, biodiesel, hydrogen, biobutanol, among others) (Croezen et al., 2009; Demirbas, 2008; Sánchez et al., 2007). The economic (competitiveness) and environmental performance (potential environmental impacts) have been exhaustively analyzed (Gaffney et al., 2009; Hu, et al., 2004; Puppán, 2002; von Blottnitz et al., 2007). Recently, social impacts have been discussed (food security, land use, health effects and employment) (Hall et al., 2009; Phalan, 2009).

In the Colombian context, bioethanol and biodiesel are being used as climate change mitigation strategy, as well as bioenergy alternative systems. Bioethanol from sugarcane is used as gasoline additive. The feedstocks which have been potentials in Colombia are: Sweet crops (e.g. sugarcane), starchy crops (e.g. cassava) and lignocellulosic materials (e.g. agro industrial wastes). The design data can be available, but integral environmental assessments have not carried out. In the case of biodiesel, its production is based on oil-palm. In addition, Colombia has a high agronomic potential for its production. The Federación Nacional de Biocombustibles de Colombia indicates the existence of six biodiesel production plants producing 560000 t/yr, which generate 16060 direct and 32120 indirect employments (using 0.1% of available arable land).

Although some studies show that the GHG emissions decrease during the biofuel production process, the exact GHG amounts associated to biofuels supply chain are not completely clear (Börjesson, 2009; Demirbas, 2008; Havlík et al., 2011; Ryan et al., 2006). Big efforts have been made by the scientific community, but approaches, assumptions and results have not allowed the generalization of the methodologies (Börjesson et al., 2011; Cherubini, 2010; Larson, 2006).

In this chapter, the GHG quantification throughout bioethanol and biodiesel supply chain is proposed as the route to determine the relationship between Colombian biofuels production, biofuels use and climate change.

CURRENT COLOMBIAN BIOFUELS SUPPLY CHAIN

The energy in Colombian context includes primary and secondary sources. Nevertheless, the most important change of the energy matrix is associated to biofuels (bioethanol and biodiesel) production. Both bioethanol and biodiesel supply chains have been implemented inside important agroindustrial supply chains: Bioethanol is related to sugar chain; biodiesel interacts with oleaginous chain. Following, the major features of biofuels supply chain are explained.

Feedstocks

At industrial scale, bioethanol is produced from sugarcane; biodiesel is produced from oil-palm; a new industrial plant uses cassava like feedstock (CUE, 2012).

Bioethanol

In Colombia there are several potential feedstocks for bioethanol production; for instance, wheat, corn, barley, sweet sorghum, which are obtained in the country (Ministerio de Agricultura y Desarrollo Rural, 2011); moreover, some studies have been carried out using sugar beet as feedstock (Román et al., 2007). However, bioethanol is produced mostly from sugarcane because this feedstock presents key advantages with regard to others:

- It is the sugar-crop which has the most photosynthetic efficiency, meaning high crop yield.
- Sugar industry in Colombian context has been based on sugarcane, the infrastructure and experience required start with this know-how.
- Sugar supply chain was adapted for sugar and bioethanol production, taking into account the food security issues. Sugarcane lands were not expanded; instead of that, sugar for exportation was destined to bioethanol production. Adittionaly, Land Use Change (LUC) controversies, internal sugar supply assurance, among other critical facts, were covered using sugarcane as feedstock.

Biodiesel

Oleagineous supply chain is major based on oil-palm and isolated crops, with high-oil contents that grow on Colombian lands, e.g. sesame, cotton, soy and peanut (Ministerio de Agricultura y Desarrollo Rural, 2011), as well as non-edible crops, such as castor bean and jatropha (Campuzano, 2011; Loaiza, 2004). These crops have been potentially used as biodiesel feedstocks. In the case of castor bean, it is most promising for obtaining other products. On the other hand, jatropha has been analyzed in the regional context, and the studies still continue (Campuzano, 2011). Using palm oil as Colombian biodiesel feedstock encloses the same reasons of sugarcane: High yields, with a developed the supply chain and technology adaptation facilities. Nonetheless, oil-palm lands have growth, implicating LUC impacts. In chapter five, the LUC associated to oil-palm is discussed.

Processing technologies

Both bioethanol and biodiesel are produced using mature technologies:

- Bioethanol (CUE, 2012): Sugarcane is milled. Rich-sugar juice is obtained by mechanical extraction. Juice is clarified, heated and exhaustively evaporated, in order to obtain sugar crystals. Concentrated juice, obtained in intermediate stages of evaporation, is known as molasses. Some fractions of molasses (molasses B) are destined to bioethanol production. Molasses B are sent to a fermentation unit. The separation of bioethanol from fermentation broth is carried out via decantation, distillation and hydration using molecular sieves. Sugarcane bagasse is used in the cogeneration system. The leaves, ash (from cogeneration system), concentrated vinases and field wastes are used in the biocompost process. Remaining leaves and field wastes stay in the field as natural cover. The wastewaters are treated via anaerobic digestion.

Biodiesel (CUE, 2012): Fresh Fruit Bunches (FFB) are obtained from field operations. The FFB is sterilized with low-pressure vapor to separate the kernel and the Empty Fruit Bunches (EFB). Kernel undergoes a digestion process with the purpose of cellular lysis. Oil is mechanically extracted. Crude oil is dried, clarified and deodorized. Refined oil reacts with methanol to produce biodiesel, which is separated by distillation. EFB is either directly used as organic fertilizer or as biocompost input. Kernel cake is treated to obtain palm kernel cake and oil cake. Glycerol, from the biodiesel separation process, is purified. The wastewaters are treated via anaerobic digestion.

Biofuels usage

Bioethanol and biodiesel are used in the transport sector. Bioethanol is blended with gasoline; the current blend is E8, i.e 8:92 Bioethanol: Gasoline (Federación Nacional de Bicombustibles, 2012). Biodiesel is blended with diesel at B7-B10 , i.e. 7:93-10:90 Biodiesel:Diesel (FEDEBIOCOMBUSTIBLES, 2012). Bioethanol must be incorporated to gasoline as close as possible to the use point because biofuel physicochemical characterization. Instead, biodiesel can be transported through polyducts blended with diesel until B4.

COLOMBIAN BIOFUELS POLICIES

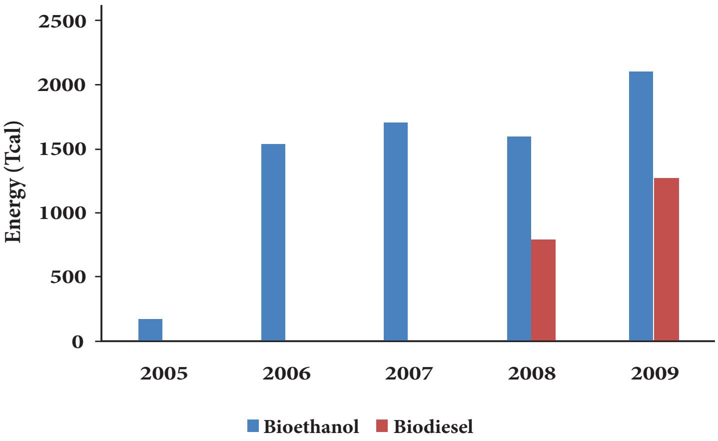
Colombian legal framework regulates the biofuels blends, tax exemption, quality standards and biofuels prices (ICONTEC - ECOFYS, 2011; Presidente de la República, 2007; Secretaría del Senado, 2001, 2002, 2004). Biofuels production is focused on fuel blends to be used in the transport sector. According to the "Unidad de Planeación Minero-Energética" (UPME), biofuels goals include the percentage increment of biofuels blends in the transport fuels (UPME, 2012). To fulfill the general biofuels aims, several exemption taxes and subsidies have been regulated (Flórez, 2011):

- The exemption of Value-Added Tax for sugarcane.
- Tax rent exemption for oil-palm.
- Tax exemption for biodiesel and bioethanol sale.
- Rent subsidies to investment projects higher than 75000 minimal wage.

BIOFUELS AND COLOMBIAN ENERGY MATRIX

Bioethanol and biodiesel production in 2005 and 2008, respectively changed the energy matrix, but their share is still low (0,06-1,14% on the total energy consumption). Figure 9.1 presents the energy production corresponding to biofuels usage. The increment tendency is notable.

Figure 8.1. Energy from biofuels in Colombia



Source: Own elaboration based on national energy balances (UPME, 2011)

The reason of biofuels production is the legislation, which indicates the obligatory use of bioethanol and biodiesel, for blended purposes (Secretaría del Senado, 2001, 2004). Hence, it is expected the biofuels share in the energy matrix increased in the next decennial.

GHG AND INTERNACIONAL SUSTAINABLE STANDARDS

Goal of biofuels production is energy security and environmental sustainability, as well as the global market inclusion or access to grant from flexibility mechanism. In this sense, sustainability should be certified by both national and international entities. Colombian certification is CES (below depicted). Table 9.1 summarizes some of the most important standards, initiatives and voluntary alliances (GBEP, 2011; Gilbertson et al, 2007; International Trade Center, 2012).

The "Federación Nacional de Cultivadores de Palma de Aceite" is member of RSPO (FEDEPALMA, 2012). In the case of bioethanol the GRI certification is in process.

COLOMBIAN ENVIRONMENTAL SEAL (CES)

The CES corresponds to a voluntary certification, which is regulated by the "Ministerio de Ambiente, Vivienda y Desarrollo Territorial" through order 1550 of 2005 (MAVDT, 2005). The CES is awarded when the environmental benefits can be proven. The most important criteria for obtaining the CES are (MAVDT, 2005):

Table 8.1. International standards applied to biofuels supply chain and GHG emissions

Name	Remarks
ABNT Ecolabel	Based on Lifecycle Assessment.
Bonsucro	Better sugarcane initiative. It is related to sugarcane supply chain.
Carbon Reduction Label	Certification awarded to Carbon Trust Footprint Certification Company based on the standards PAS2050, ISO14065:2007. GHG emissions are calculated using Lifecycle Assessment approach.
CCBA – Climate Community & Biodiversity Alliance	Certification on Forestry and Agriculture.
CSBP – Council for sustainable biomass production	Voluntary certification. It is applied to bioetanol, biodiesel and bioelectricity from wastes and short-rotation woods.
GRI – Global Reporting initiative	Voluntary certification. Consisting on the sustainable reports generation.
ISCC – International sustainability and Carbon Certification	Certification on: GHG emissions. Sustainable land use. Natural biosphere protection. Social sustainability.
RSB - Roundtable on sustainable biofuels	Guideline of principles and sustainable criteria associated to biofuels supply chain. The first certification in RSB was obtained for an Austrian's bioethanol factory (FEDEBIOCOMBUSTIBLES, 2012).
RSPO – Roundtable on sustainable Palm Oil	RSPO standard covers the production, processing and palm oil use.
Verified Carbon Standard	Voluntary certification. It is addressed to carbon market.
GBEP – Global Bioenergy Partnership	Voluntary indicator for bioenergy systems. It is addressed to national governments.

Source: Own elaboration

- National or local environmental importance of environmental savings related to any lifecycle stage.
- Technical data basis.
- Market share significance.
- Appropriated infrastructure.

Since the CES must be assigned according to technical rule, the activities related to CES are depicted following (MAVDT, 2011):

- Product selection category: In this stage, the product must be classified according to its economic activity. If the product is new, the category application must be formulated and after, the feasibility study must be carried out.
- Environmental criteria normalization: This stage comprises either technical rule writing or actualization. In the first case, the procedure implicates the rule elaboration, the public consultation, the treatment of public consultation results, and the technical rule application. In the second case, the regulation is compared to standards or current conditions.
- Enforcement: Voluntary CES obtaining.
- CES and biofuels supply chain

Biofuels supply chain, which was above-described, fulfills all criteria to obtain the CES. Thence, the strategic environmental assessment of Colombian biofuels (Palacios et al., 2008), based on the Strategic Environmental Assessment guidelines (Herrera et al., 2008), allowed obtaining a technical rule (Carrillo, 2010; Homez, 2010). This (FEDEBIOCOMBUSTIBLES, 2011) would be used in the second stage of CES activities in order to certified biofuels at the national level.

GHG EMISSIONS FROM COLOMBIAN BIOFUELS: METHODOLOGICAL APPROACH

The goal of this work was determining the GHG emissions from Colombian biofuels production and use, at current conditions. The Life Cycle Assessment (LCA) methodological approach was used as basis. The GHG considered was CO2, CH4 and N2O, with the global warming potential given by IPCC (Eggleston et al., 2006). Following, the systems are depicted.

Bioethanol from sugar cane

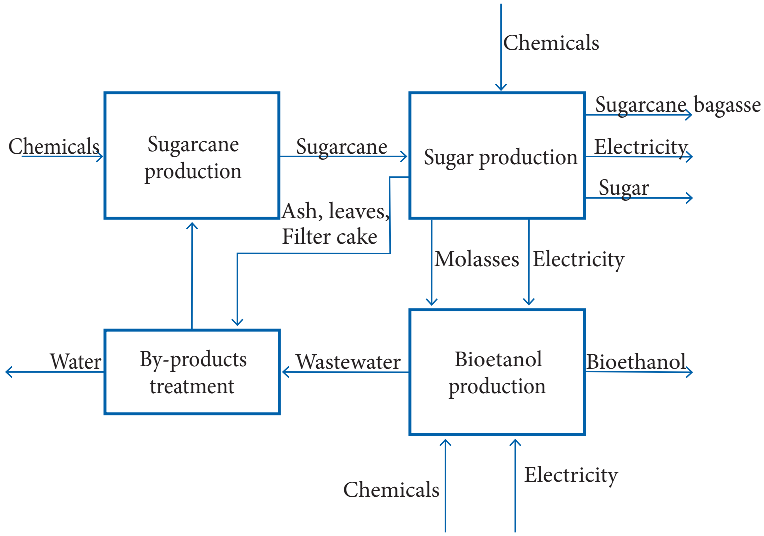
The system boundaries are shown in figure 9.2, based on the supply chain description above-mentioned.

It was considered GHG emissions from: Mechanical harvest (diesel), mechanical tillage (diesel), mechanical irrigation (diesel), lime application (diesel), lime application (direct emissions), fertilizer (N-P-K, compost, manure, vinasse, leaves), sugarcane burning, by-products treatment (wastewater treatment and biocompost production), fermentation, cogeneration system, bioetanol production, sugar production, system, bioetanol production, sugar production, E10 combustion, pesticide transport, fertilizer transport, vinasse transport, reagent transport (H2SO4, HNO3, antibiotic, metabisulfite, metasulfite, among others), sugarcane transport, bioethanol distribution and blended. The functional unit was 53600 MJ produced and used. The table 9.2 summarizes the assumptions for the GHG calculations.

Biodiesel from oil-palm

The system boundaries are presented in figure 9.3. It was considered GHG emissions from: Mechanical harvest (diesel), lime application (diesel), limes application (direct emissions), fertilizer (N-P-K, EFB, and leaves), wastewater treatment, mechanical irrigation (diesel), LUC, oil extraction, oil refinery, biodiesel production, glycerol purification, cogeneration system, Pesticide transport, fertilizer transport, EFB transport, reagent transport (methanol, NaOH, citric acid, acetic acid, among others), FFB transport, biodiesel distribution and blended. Te functional unit was 949905 MJ produced and used. The table 9.3 summarizes the assumptions for the GHG calculations.

Figure 8.2. Bioethanol production system



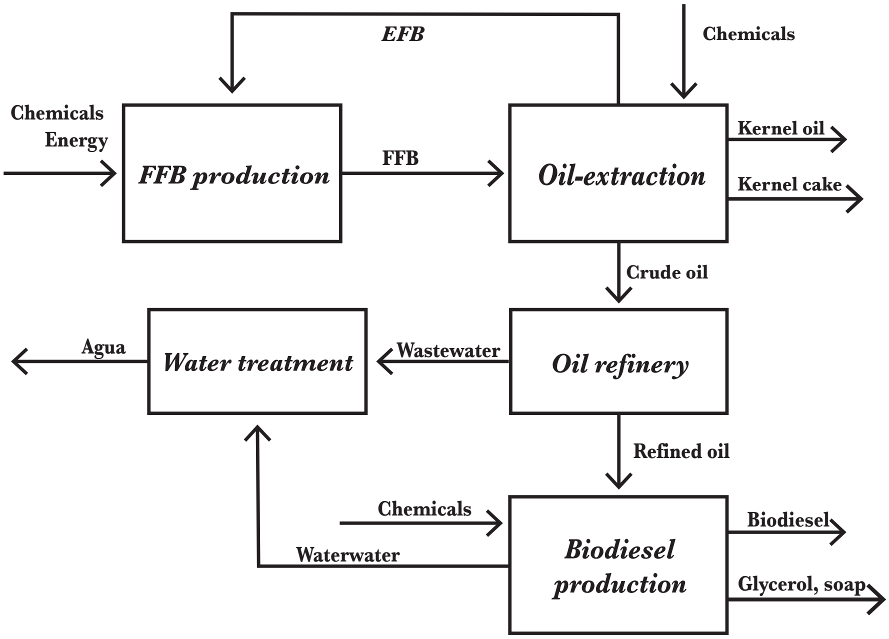
Source: Own elaboration

Table 8.2. System assumption based on the variables type

Group	Methodological approach
Engineering	Energy and mass balance were calculated using the modeling and simulation approach according to (Cardona, et al. 2009b; Moncada et al., 2008; Sánchez et al., 2008, 2012). Simulation procedures were carried out using Aspen Plus, Matlab, and Excel.
Logistic	Transport distances were obtained from (CUE, 2012). Energy efficiency was taken from (BioGrace, 2012). Final distribution of bioethanol was calculated based on (FEDEBIOCOMBUSTIBLES, 2012a) and (Instituto Nacional de Vías, 2008).
Empirical and hybrid	Emissions factors correspond to (Amaranto, 2010; Cherubini et al., 2009; Eggleston, et al., 2006). Productivities were obtained from (Food and Agriculture Organization, 2012). Other inputs (low heat value, agronomic requirements) were taken from (CUE, 2012; Ecopetrol, 2011; Leal, 2005; Torres, 1995).

Source: Own elaboration.

Figure 8.3. Biodiesel production system



Source: Own elaboration

Table 8.3. System assumption based on the variables type

Group	Methodological approach
Engineering	Energy and mass balance were calculated using the modeling and simulation approach according to (Andres Quintero et al., 2012; Cardona et al., 2008; Cardona et al., 2008; Cardona et al., 2009a). Simulation procedures were carried out using Aspen Plus, Matlab, and Excel.
Logistics	Transport distances were obtained from (CUE, 2012). The energy efficiency was taken from (BioGrace, 2012). The final distribution of biodiesel was calculated based on (FEDEBIOCOMBUSTIBLES, 2012b;Instituo Nacional de Vías, 2008).
Empirical and hybrid	Emissions factors correspond to (Amaranto, 2010; Eggleston, et al., 2006). Productivities were obtained from (Food and Agriculture Organization, 2012). Other inputs (low heat value, agronomic requirements) were taken from (CUE, 2012; IICA, 2006).

Source: Own elaboration

GHG EMISSIONS FROM COLOMBIAN BIOFUELS: RESULTS AND DISCUSSION

Bioethanol

Table 8.4 summarizes the emissions for lifecycle of E10 blend. The results indicate that the GHG savings for E10 blends production and usage are around 5% (based on the values given in (Ecopetrol, 2011).

Table 8.4. GHG emissions for bioethanol along the supply chain

Stages	Emissions (gCO_2e/MJ)
Forestry Machinery	2,45
Irrigation	0,43
Agronomical inputs transport	0,54
Lime application	0,89
N-fertilizer application	4,59
Cane burning	0,31
Sugarcane transport	0,67
Reagent for sugar production	0,02
Reagents for bioethanol production	0,01
Energy for ethanol production	0,05
Bioethanol distribution	0,30
Water treatment	5,76
Biocompost production	0,02
E10 combustion	60,00
Total	**78,60**
Energy ratio (output energy/required energy)	**6**

Source: Own elaboration

According to the national report (CUE, 2012), the direct LUC is not applicable to sugarcane, since the harvested areas have been the same in last decade. The harvest land average can be considered as the same in last decade. Therefore, the indirect LUC is the most important for this system, at current conditions. Using the estimation of organic matter loss given by (Rodriguez et al., 2009), as well as the fraction of SOC in organic matter (García et al., 2005), the SOC loss for sugar crops is 1,39 tCO2/ha·yr; i.e. 2% from initial carbon content is annually lost. The carbon loss rate could not only be considered low, but also could be an opportunity to adjust the agronomical practices, in the sense of SOC conservation.

Biodiesel from oil-palm

The oil-palm are has increased in the last years (Ministerio de Agricultura y Desarrollo Rural, 2011). Therefore, the direct-LUC becomes important in complete GHG balance. Depending on the values of the soil carbon organic, above-ground biomass and belowground biomass, the LUC effects can be either positive or negative: If the oil-palm grows over lands such as the previous usage implicates low carbon capture, the oil-palm cultivation increases the carbon stocks, indicating positive effects. Inversely, the oil-palm over high capture cover, e.g. natural forest, carries negative effects (carbon emissions).

The oil-palm crops have been major expanded in grasslands. Because the carbon capture of grasslands is lower than the oil-palm, the direct-LUC is positive, i.e. during its growth on pasture lands, the oil-palm captures carbon emissions. Following the IPCC tier 1 and the values reported in (CUE, 2012), the capture reaches 42,96 gCO2e/MJ. The indirect LUC, based on the SOC of (CUE, 2012), indicates that 1,46 tCO2e/ha·yr are storage in soils. It represents an absorption of 24 gCO2e/MJ in the biodiesel production system. Including this result in general GHG balance, the GHG saving are 10% for B10 blends, with regard to national fossil fuel report (Ecopetrol, 2011).

CONCLUSIONS

The main purpose of this work was to clarify the relationship between the biofuels supply chain and climate change. All studied feedstocks showed positive set of variable values, which could allow saying the Colombian biofuels fulfill the international standards of GHG mitigation.

The technological and environmental assessment of any process was considered as a first step to its industrial implementation. In the case of biofuels systems, the development steps were invested: The bioenergy productions were priority systems. Therefore, the discussions associated to biofuels have overcome the scientific limits. While food security, social impact and uncertainties about environmental impacts, have been related to biofuels production and use, the debate has not completely finished. Moreover, the concept of green supply chain management applied to biofuels could be considered as the most promise alternative to sustainable biofuels development.

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