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CONTENT

SESSION A: STRATEGIES

A.1. TRANSFORMATIONS OF ECONOMIC SYSTEMS: THE BIOECONOMY CASE

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Abstract

Since the industrial revolution, the economic system is continuously exposed to change and development. Starting from an agriculture based production system we are arriving now in, what is frequently called, knowledge-based economy. In between the economic production system has moved through transformation processes characterized as mechanization, mass production, electrification etc. None of these transformations appears regular and ordered. Instead, they were triggered by reaching the limits of the previous production systems and by important innovations, which most often where the result of competence destroying technical change where old industries (and actors as well as economic dynamic regions) were replaced by new industries (and new actors and new regions) with outstanding economic dynamics. From this long-term view, therefore, there is nothing exceptional on economic transformations.

However, this time, the development towards the knowledge-based economy seems not to be sufficient to solve all problems, which accumulate over the last 250 years of industrial production and many of them reached a threatening global dimension. The knowledge-based bioeconomy production system is conceptually reacting on this shortcoming of the so far undirected transformation. No longer is every innovation considered as contributing positively to the necessary developments and, not surprisingly, knowledge, which is the most important input into the development of new technologies, is considered to become an increasingly scarce resource. Concepts like responsible innovation, underlying e.g. the design of the Horizon 2020 program of the EU are clearly a consequence of these considerations.

The determination of goals in the current transformation towards the knowledge-based bioeconomy therefore is different compared to transformations in the past. Targets like protecting the climate, strong reduction of waste and pollution, a fair income distribution, etc. are superimposed to a development process, which in principle has to be an open process. Because of the openness and future-orientation there can be no strict and pre-determined formulation of well-specified goals. The challenge, therefore, has to be the design of a framework, which supports the development of the

economic system within certain guide rails, which make sure that the production system transforms this time into a sustainable system. This can only be achieved by the enormous creativity of market-based economies, which have to involve all market actors, the firms, the households, the public sector and the financial markets to support the next and required transformation of the production system.

In the 1970s the publications of the famous Club of Rome addressed the limits of economic growth. Extrapolating economic growth, the use of resources and pollution related to industrial production it became immediately clear that the current production systems based on industrial mass production and oil-based products is not sustainable. From then on, several alternative approaches are developing which all attempt to replace the holy grail of economic growth with concepts, which include protection of the environment, fair income distribution, sustainable use of resources, preventing climate change etc. Common to these concepts e.g. post-growth, degrowth etc. is the focus on sustainability and the required limitations of economic activities, in particular in the industrialized world, to achieve this goal.

Although the idea of the knowledge-based bioeconomy production system shares the critical points of these alternative approaches, the principal design is focusing on innovation to solve the undoubted limitations of the traditional growth based concept. It is important to note, that innovation has to be considered as a broad concept, which includes the supply and the demand side as well as the organization of the production in the public sector.

Since the late 18th century economic systems are continuously exposed to change and development triggered by new technological knowledge and the related diffusion of innovations. In economics, classical writers like Adam Smith and Karl Marx addressed this issue. However, with the arrival of neoclassical economics at the beginning of the 20th century and its focus on marginalism and economic equilibrium the idea of structural change and economic dynamics moved to the background. Within the optimization framework of neoclassical economics, it is impossible to address qualitative phenomena and complex dynamics of transformation processes. In the shadow of what finally became the mainstream in economics in the 1980s Evolutionary Economics, building on the work of Joseph Alois Schumpeter addressed again innovation driven structural change and economic growth and development.

A.2. A HIGHLY DYNAMIC, SELF-ORGANIZED, BIO-ECONOMY; IT'S BECOMING A SERIOUS GAME

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The notion that we have only one planet 'earth' with renewable and recyclable resources, a vulnerable interface with the troposphere and maximized solar energy is becoming more and more apparent while challenging its limits. A viable planet is a highly (or the most) complex system of which key parts are actually passing the boundary between the orderly state and the chaotic regime, revealed by exponentially changing patterns (like for greenhouse gases, loss of biodiversity, public deficits, depletion of fossil fuels, …) instead of showing sinusoidal curves. Even though the boundary layer ('melting zone') between the orderly and chaotic state has a certain bandwidth due to numerous external and internal conditions, allowing complex systems being dynamic and self-organized, the bandwidth is not unlimited.

Within this boundary layer, all living creatures have to respectfully play their games, challenge the rules in time but accept the upper and lower limits, being revolutionary more creative, etc. Today, incremental innovations showing 10% improvements may motivate us, however, this is often far from sufficient. If we currently use 6 planets for our daily living conditions, we need to radically change numerous activities with at least a factor of 10 as soon as possible.

Here, we face a 21st century paradox in the bio-based economy: the efficiency thinking or economy of scale concepts drives us towards in general upscaling and homogenization of production processes (food, biomaterials, biomolecules, …), however, the environmental and social factors force us towards biodiversity, product differentiation, respecting cultural identities, etc.

Some preliminary suggestions are here presented, that may counteract the paradox, in the area of targeted, down-sized, technologies, alternative resources and new business concepts.

A.3. STRUCTURAL CHANGE, KNOWLEDGE AND THE BIOECONOMY

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The bio economy is a major transformation of the world economic system. Such system has been dominated since the beginning of the XXth century by petroleum. The bio economy promises to replace fossil based productive processes with processes using renewable inputs. In so doing the bio economy would disturb a large number of existing relationships by, for example replacing oil suppliers with suppliers of renewable raw materials (biomass). According to some analysts the bio economy could offer considerable opportunities to the LDCs and to the emerging countries endowed with the factors needed to produce the required types of biomass. While there is some truth to this claim the bio economy is likely to be highly knowledge intensive. Trends in knowledge have already shaped the applications of biotechnology to the pharmaceutical, medical and agrochemical fields. Although the developments of the bio economy will increasingly be to the industrial field (chemicals, energy, environment etc) it is difficult to expect different development path in this respect. As a consequence, the countries and the firms closest to the frontier of knowledge relative to the bio economy are more likely to profit from the transition to the bio economy than the pure suppliers of raw materials, even if these are natural and renewable.

A.4. BEYOND PRODUCTION –INNOVATIONS, VALUE CHAINS AND KNOWLEDGE INTENSIVE TECHNOLOGIES FOR A VIBRANT BIOECONOMY

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Abstract

Tasmania, an island to the South of Australia's mainland, depends strongly on its bioeconomy. Currently the farm gate / beach value of the bioeconomy contributes around 7.4% to the overall Gross State Product (GSP). This figure is considerably higher than for Australia overall (2.5% of Australia's GDP is derived from the bioeconomy) and more in line with the economies of Brazil (5.7%) or New Zealand (7.2%). Taking a whole value chain perspective, it is estimated that the bioeconomy currently contributes between 16 to 20% to Tasmania's overall economic performance. The Government's target is to strongly grow this sector over the next few decades. To achieve these growth targets, an irrigation-led transformation is currently underway. This investment in irrigation infrastructure must be underpinned by similar investments in innovations, value chains, knowledge creation and dissemination for these ambitious growth targets to be achieved.

Summary

The bioeconomy[1] underpins all economic growth and development; without the development of agriculture over 10,000 years ago, the astounding transformational shift in human behaviour that resulted in the creation of our civilisations would not have been possible. Agriculture provided the foundation on which other sectors of our economies could develop and grow. The efficiencies created by agriculture – the ability to reliably feed growing populations with fewer and fewer farmers – meant that no society has ever turned away from it (Leith and Meinke, 2013). As a consequence, the contribution of agriculture to large and highly developed economies today is only about 1 – 3% of their Gross Domestic Product or GDP (Table 1).

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[1] Here I used the definition by the European Commission that defines the bioeconomy as *the sustainable production of renewable resources from land, fisheries and aquaculture environments and their conversion into food, feed, fibre bio-based products and bio-energy as well as the related public goods. The bioeconomy includes primary production, such as agriculture, forestry, fisheries and aquaculture, and industries using / processing biological resources, such as the food and pulp and paper industries and parts of the chemical, biotechnological and energy industries.* (http://ec.europa.eu/research/bioeconomy/policy/bioeconomy_en.htm).

The proportionally low farm gate contribution of agriculture to developed economies' GDPs is a direct result of the efficiencies created by agriculture; efficient food and fibre production allowed labour resources to be deployed elsewhere, creating other economic sectors that now dwarf agriculture's economic value. In other words: while the relative economic importance of agriculture has diminished over time, its social and political importance has never been questioned. It is this special status of agriculture as a pillar of our societies that requires particular attention in terms of policy support for research, development and education.

Table 1: Percent of agriculture as a contributor to GDP, based on farm-gate value as well as current population numbers for a range of countries and the Australian State of Tasmania (World Bank, 2015; Australian Bureau of Statistics, 2013; Tasmanian Govt, 2015).

Country	**% of GD/SP**	**Population (million)**	**as of**
UK	0.7%	64	2013
Germany	0.9%	81	2013
Japan	1.2%	127	2012
USA	1.3%	316	2012
France	1.7%	66	2013
Netherlands	2.0%	17	2013
Australia	2.5%	23	2013
Brazil	5.7%	200	2013
New Zealand	7.2%	4	2010
China	10.0%	1,357	2013
Fiji	12.2%	>1	2013
Indonesia	14.4%	250	2013
India	18.2%	1,252	2013
Vietnam	18.4%	90	2013
Papua New Guinea	36.3%	7	2012

Australia's agricultural farm gate value contributes 2.5% to the annual GDP. When accounting for the value-adding processes that food, fibre and other bio-based products go through once they leave the farm, along with the value of all the economic activities that support farm production through farm inputs, food manufacturing, transport and logistics, wholesaling and retailing and the food service sector, agriculture's contribution to Australia's GDP increases to around 12% or $155 billion (National Farmers Federation, 2015). Agriculture in Australia is now a knowledge-intensive sector of considerable societal relevance. The 2.5% of farm gate contribution by the bioeconomy to Australia's GDP is at the higher end for a fully developed economy, indicating the importance of renewable, primary production for Australia. This is in contrast to the extractive industries such as mining that until recently have dominated the economic debate in Australia.

However, this figure of 2.5% masks some considerable variability across the eight States and Territories that constitutes the Federation of Australia. Economic activities are unevenly distributed and each state's contribution to Australia's GDP varies considerably, as indicated by their own Gross State Product (GSP; Table 2). Agriculture's contribution to the GSP of each State for the 2012/13 financial year varied from 1% for Western Australia to 7.4% for Tasmania (excluding the Australian Capital Territory of Canberra, ACT, where no primary production takes place). There are many reasons for this diversity that go beyond the scope of this paper. Here I focus on Island State of Tasmania, where proportionally the bioeconomy plays the most important role. Estimates of the post-farm gate / post-beach contribution of Tasmania's bioeconomy to the overall economic performance of the State range between 16 - 20%.

Table 2: Economic snapshot of the bioeconomy's contribution to all Australian States and Territories and Australia as a whole; 2013 data: Gross State Product (GSP), GSP per person, farm gate or beach value of the bioeconomy (Australian Bureau of Statistics, 2013)

	GSP ($ million)	**GSP per person**	**Farm gate or beach value of bioeconomy ($ million)**	**Bioeconomy's contribution to GSP (%)**	**Population (million)**
Tas	24,191	47,222	1,790	7.4	0.51
SA	94,210	56,674	4,805	5.1	1.66
Qld	294,548	63,840	7,953	2.7	4.61
Vic	333,393	58,682	8,001	2.4	5.68
NT	19,860	83,828	338	1.7	0.24
NSW	471,354	64,098	6,599	1.4	7.35
WA	252,999	102,232	2,530	1.0	2.47
ACT	34,414	90,631	0	0.0	0.38
Australia (GDP)	**1,524,969**	**66,549**	**38,124**	**2.5**	**22.91**

Tasmania, an island located at the southern tip of South-eastern Australia comprised of about 68,000 km^2, is roughly the size of Sri Lanka or Ireland. Located in the 'roaring 40s', around 42°S in the Southern Ocean, Tasmania has a cool to mild climate ideally suited for a very wide variety of crops, pastures, livestock production and aquaculture. Average annual rainfall ranges from 2700mm in some highland locations to 450mm in parts of the Central Midlands. Its climate and topography, that contributes to orographic lift, means that although Tasmania only has about 1.5% of Australia's productive landmass, it has access to about 12% of Australia's fresh water reserves, largely located in highland lakes and dams as a consequence of the large hydro-electric schemes of the 1950s and 60s. This abundance of surface water makes irrigation-based growth of the bioeconomy particularly attractive. It also leads to new challenges to ensure that this valuable resource is appropriately deployed without causing damage to fragile soils and environments.

By Australian standards, Tasmania's bioeconomy is characterised by an unparalleled diversity as a consequence of its geography, history, climate and other geo-political factors. Its relatively small size, surrounded by the pristine waters of the Southern Ocean and the distance from the mainland means that extensive agriculture based on low-value bulk commodities will never be the dominant primary products. Instead the island is rapidly developing a reputation for high quality, often niche products, value adding, agri-tourism and fine food and beverages. Agrifood and other products range from traditional commodities based on dairy, beef, sheep, vegetables, wine, fruit (such as cherries, berries and nuts), oysters, abalone and salmon to medicinal opium poppies (Tasmania produces about 50% of the world's legal opiates such as morphine, codeine and thebaine), pyrethrum (75% of current world demand for pyrethrum is serviced from Tasmania) and various essential oils.

A further increase in the profitable and sustainable production of these and other bio-based products, particularly those founded on a reputation for "clean and green", requires entrepreneurism, functional and transparent value chains, innovation, proactive risk management and knowledge creations and sharing. I will briefly outline this challenge using the current rollout of new irrigation schemes across Tasmania as an example:

Right now Tasmania is undergoing a phase of unprecedented intensification and transformation of its primary production sector. The Tasmanian Government's AgriVision 2050 policy (http://bit.ly/1MxuovX) sets a huge stretch target for Tasmania's bioeconomy, namely increasing the farm gate and beach value of the bioeconomy to an annual value of AUD$10 billion by 2050, up from AUD$1.8 billion in 2012/13 (Table 2). Although this vision is underpinned by significant investment in irrigation infrastructure – about AUD$500 million of private and public funds have already been invested in new irrigation schemes – realising and sustaining the benefits will require substantial investment in knowledge infrastructure, innovation platforms, value chain approaches, benchmarking and monitoring (Fig. 1).

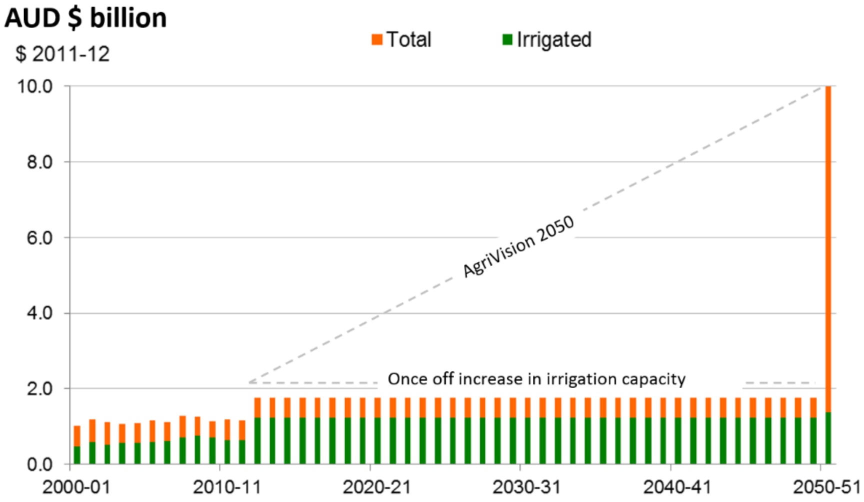

Fig. 1 Tasmania’s research and innovation challenge: the AUD $10 billion target for 2050

Achieving this vision necessitates, for instance, a dramatic increase in the value derived from each litre of irrigation water. For example, if 80% of the $10 billion target is to be achieved via irrigated agriculture, the value generated from irrigation water has to increase from currently AUD$3,500 to $16,000 per ML of water. The only pathway for achieving such an ambitious target is through targeted, applied RD&E. Researchers from multiple disciplines must work with industry and policy makers to achieve such a transformation. A key question for Tasmania is how such intensification can be economically, socially and environmentally sustainably achieved. Using an Agricultural Systems Research (ASR) approach, industry experts, academics and farmers are jointly investigating improvements in four key areas:

1) On farm systems (productivity, management systems, precision technologies, new crops and processes)

2) Business models (investments, processing, branding, marketing and exporting)

3) Natural resource management (landscape health, ecosystem production, maintaining soil productivity, drainage, waterlogging, salinity, interactions between on-farm and landscape scale)

4) Research, development, extension and education (arrangements and institutions, effective innovation, education and adoption)

Tasmania’s situation exemplifies how modern agriculture and aquaculture are now highly knowledge intensive systems that can no longer rely on single innovations such as the ones that powered the green revolution of the 1960s and ’70s. Norman Borlaug’s contribution to agricultural science and plant breeding resulted in high-yielding, disease resistant crops that saved about a billion people from starvation. Borlaug and colleagues managed to find a very effective technological fix to overcome resource limitation. Much thinking, knowledge and insight went into the creation of these technologies, yet their application was relatively simple. Now, during the first quarter of the 21st century, the challenge to our agricultural and food systems is different. This time it is not only about increasing yields per area, it is about increasing productivity without additional resources, without negative environmental and social impacts; it is about the quality, equity and accessibility to bio-based products, and all of this is into landscapes that are increasingly be contested for other societal needs such as energy production, urban expansion and a desire for landscape amenity and biodiversity conservation. Over the last decades we have moved from a situation when knowledge came embedded in the inputs delivered to the farm (e.g. hybrid seeds, mineral fertilisers, etc) to a situation where farmers now need to be highly skilled, knowledgeable and technologically savvy if they want to partake in the bio-based revolution that is taking place. Opportunities abound but engagement and investment decisions are not simple, markets and value chains are globalised and production methods are more scrutinised and determine market access.

In the case of Tasmania, 'just add water' will not result in the desired step change in value creation. For this to occur we need functional and transparent value chains, highly knowledgeable and technically skilled farmers and public-private partnerships that are based on trust, shared values and the co-creation of knowledge. We also need institutional arrangements that connect our universities effectively with policy makers, farmers, farm advisors, agribusinesses and communities: we need to recognise that innovation in agriculture will occur in a richly interconnected system of actors. Innovation requires an environment conducive to the interplay between society, producers and industry. The current and unfolding expectations of societies is embodied in market choices and social licence to operate for agriculture, and regulations and processes implement by their government. The practical needs and concerns of agribusiness in securing markets and creating profit will influence receptivity to change and disruption, and be strongly shaped by information and innovation that influences the options available. Producers themselves have aspirations and capacity that will affect the uptake of innovation.

In pursuing global food security, and more locally embedded food-systems as a pillar of Tasmania's society and economy, we need to recognise that these are top-down constructs that will be shaped and influenced by policy and institutional setting, but that in the end will be implement by farmers and agri-business leaders pursuing economic ends. This will be an area of rich social dialogue, and in the process, norms, values and world views are and will be challenged and nearly every proposed 'solution' is likely to be contested at some level. Trade-offs will be inevitable and compromises will have to be reached, particularly in instances where farmers' economic viability is often driven by short term gains that can compromise their long term sustainability. Tasmania is a microcosm that might offer insights for other societies and economies in transition.

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A.5. INNOVATION NETWORKS IN THE BIOECONOMY: THE CASE OF SUGARCANE IN BRAZIL

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Extended Abstract

The shift from a fossil-based to a bio-based economy requires better utilization of the entire biomass that that can be generated from agricultural production. The awareness that the conventional fossil fuel based economy is not sustainable any longer drove several countries to develop a bioeconomy strategy. Bioeconomy is the attempt to rethink the current economic system and make it more sustainable by increasingly sourcing components from renewable feedstock for the production of materials and energy besides the traditional production of food and feed. To reach economic profitability, innovative solutions have to be forged early enough to be readily available and economically efficient by the time they are the only alternative. Within this context, the demand for biomass raw material is sharply increasing and there are indeed countries that have an advantage to supply high quantities of high quality feedstock. One of them is Brazil. Brazil's comparative advantages are climate, geography, and the fact that it can rely on a long sugarcane growing history. Moreover, the country can build on a strong institutional landscape that helped to develop an economic comparative advantage in sugar production (UNICA, 2013). In view of the significant amount of arable land and the favorable conditions for biomass production coupled with the well-established sugarcane industry Brazil has the potential to become a role model for the global development of the of the bio-based industries.

The paper applies the "biomass-based value web" concept as an analytical approach to capture this new dimension of the bioeconomy. The biomass-based value web concept extends the commodity-oriented value chain approach and to include alternative use options of crop biomass and the potential by-products that arise during production and processing. In addition the role of innovative networks that represent the base for a strong national innovation system has not been investigated so far for the Brazilian sugarcane sector. Considering the new challenges and opportunities that come up in the bioeconomy, this aspect is particularly interesting. In this context, a new set of actors has to be considered, due to the shift from a food-supplying sector to a biomass-supplying sector, and due to an increasing relevance of the industrial use of agricultural products.

The first objective of this paper is to assess the interactions between the stakeholders that act in the sugarcane sector, and to assess the role of collaboration for the development of innovations that are relevant for the upcoming bioeconomy. We applied the national innovation system approach (NIS) since the notion is well suited to capture the variety of the actors involved and analyze the determining factors that make up the innovativeness of the sugarcane value web (Lundvall et al., 2002; Freeman, 2002). Furthermore, the innovative value web concept is applied to determine the potential of sugarcane as feedstock to become a real alternative to fossil fuels in the bioeconomy. For an analysis of the new cross cutting concept of bioeconomy the sector definition does not apply. Therefore the value web is used to define the theoretical framework of the research on the innovation system in the case of sugarcane in Brazil.

The 'sugarcane value web' served as a tool to identify the respondents for the expert interviews and underline the bioeconomic perspective of the research. Freeman (2002) states the necessity of synergies within science, technology, economy, policy and culture along with complementarity between regions and the whole country. There are several aspects which determine the performance of a NIS such as the type of relationships between actors. Non-market oriented and stable (long term) relationships of actors are improving the information transfer as well as interactive learning because the actors can build on "power, trust and loyalty" (Lundvall et al, 2002, p. 218). To analyze the concentration and interaction of different agents and fields in a national system of innovation the social network analysis is suggested (Pyka 2002). This work focuses on the three main centrality measures for degree, closeness and betweenness of an innovative network described in Buchmann & Pyka, (2014). The combination of the two approaches allows to investigate the type of linkages between stakeholders and to include all the actors that participate in the innovation system and are thus, contributing to the development of the Brazilian bioeconomy. To assess the challenges and opportunities of the stakeholders involved in different "branches" of the value web in-depth interviews were conducted. To clearly represent the outcome and make the result significant for the larger 'sugarcane web sector' the actors were clustered into 16 groups according to their role. This allowed summarizing the output from the interviews and the net-map exercise in one final map. The three linkages identified between the actors groups are: knowledge flows (formal & informal including personnel), fund flows and business linkages (e.g. joint projects and market collaboration). The emerging links are analyzed with the social network analysis method. The UCINET software developed for social network analysis was applied to derive statistical measurements as degree, closeness and betweenness centrality among actors.

The aim of this work is to investigate if Brazil and in particular the sugarcane industry, is currently able to make use of the considerable feedstock advantage, to take the lead in the development of bioeconomic uses similar to how it happened in the biofuel sector. Since the beginning of the ethanol programme in the 30's, the government supported the sugarcane sector. According to Hira & Oliveira (2009) the key aspects of state support from a historical point of view are: the continued support to the infant industry first and after the market crisis, secondly investment in long term infrastructure including R&D that allows sugarcane and the marketing of its products to increase efficiency and finally the deregulation of the state support once the market was well established. The authors argue that the government support led to the technology innovation of the flex fuel cars, which was the ultimate innovation that made the ethanol market sustainable (Hira & Oliveira, 2009). The recent valorisation of the bagasse, as raw material for the generation of electricity had a positive effect on the share of renewable sources of energy on the overall country energy mix, but contributed also to reduce the production costs of the mills, since a by-product gained economic value. By exploring the biomass value web, further products and uses were identified that bear the potential to contribute to the innovativeness of the system and could be conducive for the development of the bioeconomy in Brazil.

Furthermore, the analysis of knowledge flows in the biomass web produces interesting results. A high level of flowing knowledge can be regarded as one of the drivers of development of the bioeconomy in Brazil. The findings show that especially actors of the private sector (national and international chemical industry) which are expected to play a crucial role in the development of highly technological products report very low scores in both degree centrality and closeness centrality. When examining the business linkages scores for the three centrality measures, the high scores of the international chemical industry as well as the role of ethanol producers, the capital good industry and the mills and the national breeder institution are central. The linkages in the adjacency matrix substantiate the previous findings: from the total of possible linkages between industry and public research institutions 80% are actually maintained, whereas only 12% of the possible intra-industry connections are realized. Linkages between public funding institutions and the private industry are 40% of the total, but the public research institutions enjoy 75% of the possible connections.

When addressing the issue of barriers several respondents reported that the obsolete bureaucratic system that the universities have to comply with is hindering a stronger knowledge exchange and collaboration among universities as well as with the private sector. Furthermore, technology-intensive sectors in Brazil seem to have difficulties to compete with the international biotechnology that has a longer experience and stronger financial means to develop. The adjacency matrix illustrates that the industry shares only few links. For an innovation network this kind of linkages are crucial, since otherwise the knowledge generation is slower and more costly (Pyka & Saviotti, 2001; Buchmann & Pyka, 2014). As mentioned in the interviews this also implies that international firms bring the biotechnology knowledge to the national companies but from there is limited or no knowledge transfer or involvement to local research or education institutions.

Brazil reached impressing agronomic achievements in the sugarcane sector that lead to price competitive products and feedstock. However, new challenges have to be addressed when it comes to competing for new knowledge-intensive high-technology products and processes. The analysis revealed challenges that come with the development of the bioeconomy in the sugarcane value web. Brazil demonstrated the viability of an alternative to the use of fossil fuels and the willingness to shape markets and technologies towards a bio-based system. To be competitive among countries that have a longer history in biotechnology, some hurdles have to be overcome and incentives to foster the innovation system have to be addressed. First the bureaucratic system that supports the collaboration between the private sector and the public institutions should be simplified and made transparent for all actors involved. Secondly, international actors should be stimulated to collaborate and create knowledge exchange especially in the biotechnology sector. And to conclude, public funding should stimulate industry relevant research topics with special attention to the upcoming bioeconomy in Brazil.

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A.6. DERIVING A CONTINGENT EFFECTIVENESS MODEL FOR MEASURING THE EFFECTIVENESS OF TECHNOLOGY TRANSFER IN THE BIOECONOMY

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Keywords: Bioeconomy, innovation, technology, technology transfer, effectiveness.

1. Introduction

The bioeconomy has a high innovation potential. Thus, it can convert new scientific and technological inventions into marketable products. This innovative capacity and its potential for commercial application in a wide range of different scientific disciplines and industries bring the issue of technology transfer into sharp focus. The European Commission has also recognised the importance of supporting technology transfer in the bioeconomy by encouraging the creation of knowledge transfer networks [1]. Moreover, the success of the bioeconomy will also depend on the ability by which knowledge, inventions and technologies in the bioeconomy can be transferred from basic research to a successful commercialization of products on the market.

Technology transfer is an important part of the innovation process [2, 3]. Various definitions and concepts for technology transfer have been discussed in literature − based on different perspectives and purposes of the research [2], and on the disciplines of the research [4]. Researchers, developers and receivers of technology are likely to have different perceptions about the concept of technology transfer. In the same line, the concepts of 'technology transfer' and 'knowledge transfer' have often been used interchangeably in literature although some others clearly differentiate between these two (see e.g., [5]).

Based on the above outlined considerations and for the purpose of this paper, we understand technology transfer as a two-step process, encompassing the transfer of an idea, invention or technology from academic research to applied research (step 1) and then from applied research to commercialization on the market (step 2). For any technology transfer process to succeed, these two key steps need to be followed. The first step involves the development of a particular idea or invention into a prototype application or product. In this first step, universities and research institutes are an important source of inventions that may result in new technologies of commercial significance [6]. This becomes even more important for some industries, such as biotechnology, where companies rely heavily on universities for very basic scientific research [7]**.** This finding suggests that the process of technology transfer becomes even more important in the bioeconomy as biotechnology is one of the main innovation drivers of the development of the bioeconomy and is an important part of the bioeconomy. The second key step relates to the final commercialization of the product.

The aim of this paper is to firstly, investigate how technology transfer from research facilities to industry applications takes place in the bioeconomy, and secondly, to develop a conceptual framework that can be used to measure effectiveness of technology transfer in the bioeconomy.

2. The emerging bioeconomy: Definition, characteristics and technologies

Definitions of the term bioeconomy are plentiful. For the purpose of this paper, we consider the initial definition of this term given by the European Commission [1]. Following this definition, the bioeconomy "encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy" [1]. Based on this definition, the bioeconomy comprises three main final products: food and feed, bio-based products and bioenergy.

Although the definitions of what is understood by 'the bioeconomy' broadly differ, most of them are basically consistent regarding the following five characteristics. Firstly, innovation is at the core of the bioeconomy [1]. Secondly, the bioeconomy involves different and diverse scientific disciplines (e.g., life sciences, agronomy, ecology, food science, social sciences, biotechnology, nanotechnology, information and communication technologies and engineering) [1]. Thirdly, applications can be found in a wide range of different industries and sectors (e.g., agriculture, forestry, fisheries, food, pulp and paper production as well as parts of chemical, biotechnological and energy industries) [1]. Fourthly, the bioeconomy requires increasing cooperation among different industries. Finally, the industry changes rapidly as a consequence of new scientific discoveries and technological developments.

In addition to these core elements, it is widely accepted that the bioeconomy is a very recent discipline in early stages of its development. Inventions and technologies in the bioeconomy have achieved very different levels of maturity so far (varying from real basic research to advanced applied research). Therefore, not all inventions and technologies in the bioeconomy are already economically viable to be fully commercialized [8]. This also differs across final products (here we recall the core elements that have been examined in the previous paragraph). For instance, food and feed, and to a lesser extent, bioenergy are already more developed and the derived products are already on the market; but bio-based products are not fully mature yet [8].

All these findings suggest that many inventions and technologies in the bioeconomy are still in the first step of technology transfer (from basic to applied research), especially when it comes to bio-based products. Thus, technology transfer must be supported to contribute to the evolution of the bioeconomy in all its wide range of final products [9].

3. Technology transfer models

Many models, methodologies and evaluation criteria have been proposed in literature to assess technology transfer and to measure its effectiveness [2, 10–12]. BOZEMAN proposes a model that explains how technologies are transferred and how the effectiveness of the transfer is understood in terms of different dimensions [2]. This model, contrary to other technology transfer models [11, 12], gives the possibility to assess the effectiveness of the transfer by applying different criteria, and not only to that effect if the technology will be successfully transferred or not.

The BOZEMAN model recognises five dimensions associated with technology transfer that determine the effectiveness [2]: (1) characteristics of the transfer agent (who is doing the transfer), (2) characteristics of the transfer media (how the transfer is done), (3) characteristics of the transfer object (what is being transferred), (4) the demand environment (factors that influence the transfer), and (5) characteristics of the transfer recipient (to whom the technology is transferred). The interaction between these dimensions determines the effectiveness of the transfer process. The model also includes effectiveness criteria associated with the technology transfer. These effectiveness criteria are the following [2]: (1) "Out-the-door" (if the technology was transferred at all), (2) market impact (if the transferred technology had an impact on the firm's sales or profitability), (3) economic development (if the technology transfer efforts led to regional economic development), (4) political (if the technology agent or recipient benefited politically from participation in technology transfer),

(5) opportunity cost (the impact of technology transfer on alternative uses of resources), (6) scientific and technical human capital (if the technology transfer activity led to an increment in capacity to perform research), (7) public value (if the technology transfer enhanced societally shared values) [10].

4. Methodology

In order to elaborate a successful model which is capable to assess the effectiveness of technology transfer in the bioeconomy, its characteristics needs to be linked to the particularities of the bioeconomy. Thus, as part of the second research objective of this paper, we attempt to develop a conceptual framework to measure effectiveness of technology transfer in the bioeconomy by adapting BOZEMAN's "Contingent Effectiveness model of Technology Transfer" to the bioeconomy.

In order to ensure that the conceptual framework addresses the right issues, this study employed expert interviews with researchers selected from the *Bioeconomy Science Center (BioSC)*. The BioSC is a competence centre that functions as an interdisciplinary platform linked to the NRW bioeconomy strategy. Three universities and one research institute in NRW are members of the BioSC (RWTH Aachen, University in Düsseldorf, University in Bonn and the Jülich Research Center). The BioSC represents a variety of different research areas: (1) Sustainable plant bioproduction and resource stewardship, (2) Microbial and molecular transformation of resources into materials, (3) Process engineering technologies for renewable resources and (4) Economy and social implications of the bioeconomy.

In total four research group leaders (representing the research areas (1), (2) and (3)) were invited via email and personal phone calls to participate in the expert interviews planned to take place in the third week of June 2015. All four experts contacted accepted to participate in the study. Interviews were conducted personally, lasted around 30 to 45 minutes, and were digitally recorded. The interviewer introduced the aims of the project as well as the goals of the expert interviews. The interviews consisted of two sections and 13 questions in total. The first section was named as *"General technology transfer questions"* and consisted of seven questions about experiences of researchers in technology transfer, role of academia and industry, experiences with technology transfer offices, instruments used to transfer inventions (linked to the transfer medium dimension following [2]) etc. The second section *"Bioeconomy-related technology transfer questions"* included questions linked to the "Contingent Effectiveness model of Technology Transfer" [2]. Thus, the research group leaders were asked about the main factors that affect technology transfer in the bioeconomy (linked to the transfer agent and recipient dimensions following [2]) as well as the main external factors that influence the development of the bioeconomy (linked to demand environment dimension following [2]). At the end of the interview, the interviewer asked for any final comments or remarks, thanked for the participation and closed the interview.

5. Results and Discussion

This section shows the application of the ''Contingent Effectiveness Model of Technology Transfer'' into the bioeconomy technology transfer processes from universities/research institutes to industry partners.

5.1. Dimensions of the Contingent Effectiveness model adapted to the bioeconomy

As discussed in section 2, technologies in the bioeconomy are in early stages of development and the particular stage of maturity also again varies according to final products or sectors. For this reason, it is necessary to establish the division of technology transfer between the two key steps that have been elaborated in section 1. The first step of technology transfer involves the development of an idea or invention from basic to applied research. This corresponds to inventions or technologies in its infancy. The second step of technology transfer comprises transfer from applied research to market. This matches with technologies that have achieved some maturity or are already ready for commercial production. Therefore, the dimensions are elaborated in the following paragraphs:

The *transfer agent* is the organisation/institution seeking to transfer the technology. Applying this to the bioeconomy, the transfer agents are represented by universities and research institutes working on basic research in bioeconomy-related fields. In the second step of technology transfer, the transfer agents are applied universities, research institutes and companies with R&D units specialized in bioeconomic related areas which are active in clear applied research.

The *transfer medium* illustrates the instruments (formal or informal) by which a technology is transferred. Instruments that are used to transfer inventions and technologies in the bioeconomy include: Scientific literature, conferences, workshops, patents, research mobility, licenses, academia and industry collaborations, science parks or spinoffs. The first five instruments are more used in the first step of technology transfer, when the research is still focused on basic findings. On the other hand, licenses, academia and industry collaborations, science parks and spinoffs are instruments that are used when a particular technology has demonstrated a higher degree of readiness. Thus, they are more important in the second step of technology transfer.

The *transfer object* encompasses the content and form of what is transferred. Knowledge, inventions, technologies, devices, machines in the bioeconomy or bio-based processes are examples of what the transfer objects could be in the bioeconomy. The first step of technology transfer refers primarily to knowledge or processes, whereas the second step of technology transfer includes prototype applications of technologies, devices, or machines.

The *transfer recipient* is the organisation/institution receiving the technology (transfer object). On the one hand, applied universities and research institutes receive basic research or ideas to be further developed. These are included in the first step of technology transfer. On the other hand, companies in areas of food and feed, chemicals, energy, biotechnology etc. receive prototype applications or already developed technologies, and thus are the main technology recipients in the second step of technology transfer.

The *demand environment* refers to factors (market and non-market) related to the transfer object. In a recently published report on the hurdles hindering the development of industrial biotechnology [13], four main categories of barriers that can also be attributed to the bioeconomy are highlighted: (1) feedstock supply (e.g. high biomass prices, uncertain biomass supplies, seasonality), (2) production (e.g. potentially high R&D costs, low yields, high costs of scaling up production, missing bioprocessing technologies and tools), (3) market (e.g. regulatory constraints, poor consumer demand to bio-based products), (4) innovation systems (e.g. lack of access to finance, lack of harmonised intellectual property rights, lack of public R&D funding for demonstration and commercial plants, lack of collaboration between different actors in the value chain).

5.2. Effectiveness criteria of the Contingent Effectiveness model adapted to the bioeconomy

The *"out-the-door"* criterion indicates if the technology has been transferred. Some innovations and technologies in the sectors of food and feed (including agricultural production, processing, distribution and retail) have already been successfully commercialized. However, the process of transfer can become more difficult due to regulatory approval processes, food labelling or food safety regulations which food innovations are subject to [14]. In addition, biofuels have been intensively researched, produced, and used over the past 15 years [15]. Therefore, technologies in the fields of food, feed and bioenergy have been transferred, although some limitations arise. On the other hand, bio-based products are under continued research and development and most of them have not been commercialized yet [8]. This implies that bio-based technologies are in the first step of technology transfer (from basic to applied research).

Market impact and economic development criteria measure if the transferred technology has an impact on the market (on firm's level or on regional or national scale) according to the commercial success of the technology. Following the same reasoning as in the previous paragraph, the sectors of food, feed and bioenergy have already achieved some market impact since they have already been commercialized. However, bio-based industries have not achieved yet a strong market impact [8]. This also indicates that bio-based technologies are in the first step of technology transfer (from basic to applied research).

The *political reward* criterion refers to whether the transferred technology yielded some political reward to the transfer agent and/or the transfer recipient, e.g., increasing funding. The question of whether the bioeconomy has already achieved political reward derived from the transfer of technologies is doubtful. On the one hand, the bioeconomy is gaining political attention. This is reflected by the growing number of bioeconomy policies that have been brought into being at national, EU or global level in the last decade (for a comprehensive analysis of bioeconomy policies and strategies, see [16]). This political interest has led to an increase in funding for bioeconomy projects. On the other hand, these funding projects are still in a stage of initializing new developments. Thus, receiving further funding in the future could indicate that bioeconomic technologies have been successfully transferred.

The *opportunity cost* criterion analyses impacts on other (than technology transfer) missions of the transfer agent or recipient. The various opportunities offered by the bioeconomy on the mission of the transfer agent or recipient include: increasing research, establishing new specialized research groups, providing new infrastructure and equipment, starting new research projects.

The *scientific and technical human capital* criterion focuses on the impacts of technology transfer on the enhanced scientific and technical skills, technically-relevant social capital, and infrastructures (e.g., network, users groups) supporting scientific and technical work. In this regard, the bioeconomy offers some opportunities like increasing number of collaborations between diverse disciplines, establishing new bioeconomy networks or clusters (e.g.,BECY, BioSC, CLIB2021), increasing university-industry collaborations, training new professional staff in bioeconomy-related fields.

The *public value* criterion refers to whether the technology transfer enhanced societally shared values. In the bioeconomy, as an emerging discipline, it is still too early to assess effectiveness of transfer based on this criterion.

5.3. Findings from the expert interviews

As explained in section 4, the first section of the expert interviews included general technology transfer questions. In this section, researchers reported to have diverse experiences on technology transfer (both positive and negative ones). Researchers also indicated that collaborations between diverse disciplines offer important advantages in the bioeconomy. They all reported to have or at least intend to have projects with industry. However, there was a widespread view on the existing gap between academia and industry that hinders the process of technology transfer. Furthermore, some researchers claimed to use technology transfer offices but find them inefficient. These are important elements to take into account when analysing the characteristics of the transfer agent and recipient.

Concerning the transfer medium, the experts reported to apply for patents to transfer inventions in the bioeconomy. Only one researcher reported to have initiated a spin-off. These findings might confirm our findings that most bioeconomy technologies are still in the first step of technology transfer (from basic to applied research).

Regarding the demand environment, the interviewees gave a strong emphasis on the negative role that regulations on biotechnology play on the development of the bioeconomy. Additionally, they indicated the lack of logistics and infrastructures for scaling up production, as well as the lack of bio-based processes and tools as restricting factors for the development of the bioeconomy. Thus, these three factors, in line with the report [13] , can be considered of importance in the demand environment dimension of the Contingent Effectiveness Model of Technology Transfer [2].

6. Conclusion

With the growing importance of the bioeconomy, and its potential to provide new innovations with broad commercial applicability, the issue of technology transfer becomes a key priority in the future development of the bioeconomy. A framework for measuring technology transfer in the bioeconomy has been proposed in this paper. Based on this framework, the following conclusions can be derived: Firstly, successful technology transfer must be supported to achieve the full potential of the bioeconomy. Secondly, the bioeconomy is still an emerging discipline. Thus, it is still early to measure successful technology transfer in terms of market impact or economic development. Thirdly, we suggest to measure effectiveness of transfer in terms of political reward, the impact on opportunity costs and the increase in scientific and technical human capital. These issues were highlighted by some of the interviewees as they recognized the importance for maintaining funds for bioeconomy projects, or the need for training specialized personal who can work in bioeconomy-related fields as well as personal with entrepreneurial and business skills. In further research, we aim to examine case studies on successful technology transfer in the bioeconomy (e.g., bioeconomy spin-offs), by applying the developed framework.

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A.7. EFFECTIVE USE OF PLANT RAW MATERIAL – IMPLEMENTATION OF ACADEMIA RESEARCH IDEAS IN INDUSTRIAL-SCALE PRODUCTION

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University of Copenhagen

Europe is confronted with an unprecedented and unsustainable exploitation of its natural resources. The EU policies to tackle these challenges and drive a transformation of the European economy are however subject to complex inter-dependencies between strategies addressing food security, natural resources and environment (1). Developments in bioeconomy should therefore exploit the unique opportunities of the cross-cutting nature of bioeconomy strategies. Addressing sustainable economic growth in a broader sense comprise inclusion of the value addition opportunities related to rethinking side stream exploitation from the agri-food sector as an attractive alternative to use the biomass preserving the naturally occurring constituents of the biomass. Development of economically feasible adjustments in existing industrial production facilities entail a technology input combined with estimates of process costs and market understanding.

Technology transfer from academia to industry is often challenged by factors inherent in the configuration of the university and industrial working structure. Cross-cultural communication is a major obstacle in getting relevant information in play. This paper suggests generation of a co-development culture as a promising mean to support value generation and growth in the agri-food industry.

A model for technology transfer accounting for the company type and its technology level is presented along with a case study of how university IPR has been introduced to a larger industry segment for

production of food-grade proteins and fibers from industrial side-streams, turning previous costly waste into high value products of overall value comparable to the traditional main product from the raw material. Integrating market understanding with technological opportunities has thus been shown to provide a competitive advantage with respect to successful knowledge transfer leading to faster introduction of products to the market exploiting the biomass from the potato starch industry to its full potential.

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SESSION B: BIOMASS PRODUCTION

B.1. HOW TO DEAL WITH COMPETING CLAIMS ON BIOMASS IN THE GROWING BIOECONOMY

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University of Hohenheim

The main challenge to the sustainable growth of a bioeconomy is the sustainable production and a sufficient supply of biomass. This presentation discusses approaches and concepts for dealing with competing claims on biomass for food, feed, fibre and fuel production and for securing a sustainable biomass supply in a growing bioeconomy. “Biomass supply” is defined here as the process of biomass production, harvesting, pre-treatment and transport to the processing plant gate. Despite efforts to elaborate sustainability criteria and certification systems there is still no generally accepted and operational approach to a more sustainable biomass supply. However, competing claims on biomass and agricultural land are perceived as the most important bottlenecks to increasing sustainable biomass supply in the context of food security and biodiversity conservation. Different approaches for dealing with these competing claims are discussed. The first aims at a better understanding of the drivers of competition by bringing together experts from various relevant disciplines and developing model concepts which integrate the different sectors, time dimensions and spatial scales to quantify and interrelate these drivers. The second discusses technical strategies and participatory approaches to mobilizing the sustainable biomass potential and closing the gap between the sustainable, technical biomass potential and the implementable biomass potential along the whole biomass supply chain. The potential of increasing biomass supply by technical means, such as breeding, improved crop management and reduced biomass losses in the supply chain is very high. However, it can only be implemented by mobilizing and educating all stakeholders involved, including farmers and consumers, by participatory approaches and by providing farmers with the required technical and financial means. Finally, the third approach describes the potential contributions of optimized biomass use and allocation to reduce competition.

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B.2. IMPORTANCE OF SUGARCANE IN BRAZILIAN AND WORLD BIOECONOMY

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Introduction

Sugarcane is an important crop of the Brazilian economy. Brazil shows the largest cultivated area and is the first in production of sugar and ethanol, winning the international market with the use of biofuels as an energy alternative. It accounts for more than half the sugar traded in the world and production is estimated to increase 3.25% per year until 2018/2019, corresponding to an increase of 14.6 million tons as compared to 2007/2008. For exports, are expected in 2019 a volume of 32.6 million tons of sugar. The ethanol production should reach 58.8 billion liters in 2019, more than double that recorded in 2008. Due to the increase in domestic consumption, internal consumption is projected at 50 billion liters and exports at 8.8 billion liters (MAPA, 2010).

The success of Brazilian ethanol production started in 1975 with the creation of "Proálcool" to support the production of ethanol in Brazil. This was a good example of public policy for the development of biofuels, allowing Brazil to reach the second position in ethanol production in 2008, and showing lowest production costs (AMARAL et al. 2008).

Production of sugarcane in Brazil is estimate to increase 3.3% per year until 2024, rising 884 Mt, i.e. 42% higher than the production obtained in 2008, mainly due to the increase in cultivated areas. In the same period, area is estimated to increase 2.9% per year. By contrast, the average yield fall from 2010 to 2014 due to climatic and management constraints, but should moderately increase during this projection (FAO, 2015).

Energy production from sugarcane also plays an important role for Brazilian economy. There are around 408 sugarcane mills in Brazil nowadays, and most of them produce their own energy used in the production process by burning the bagasse. This result in reduction in cost for industry operation. Some mills present also the cogeneration of electricity, allowing them to sell the exceeding energy to the cities and State, increasing the income and decreasing the dependence of other sources of energy (thermal, hydroelectricity, etc).

According to Neves and Conejero (2007), the agroindustrial system of sugarcane is complex, since for sugar, ethanol and energy production the sugarcane sector depends on suppliers of raw materials and high capital investment. After industrialization, ethanol, sugar and energy are transferred to fuel distributors, electric power systems, food industry, wholesale and retail, and export trading companies. The byproducts generated, such as filter cake, vinasse, and residual water are used as bio fertilizer in the production process, reducing expenses with synthetic fertilizers.

Planted area and production of sugarcane

Brazilian planted area and production

The Brazilian Agro-Energy Statistical Yearbook 2014, consolidating data from the agroenergetic chain of the Ministry of Agriculture, Livestock and Supply (MAPA, 2015), presents the areas planted and harvested in the country during the period 2002-2013 (Table 1). The planted area more than doubled from 2002 to 2013.

Table 1: Planted area and harvested urea of sugarcane in Brazil.

Year	**Land in hectares**	
	Planted Area	**Harvested Area**
2002	5,206.656	5,100.405
2003	5,377.216	5,371.020
2004	5,633.700	5,631.741
2005	5,815.151	5,805.518
2006	6,390.474	6,355.498
2007	7,086.851	7,080.920
2008	8,210.877	8,140.089
2009	8,845.833	8,617.555
2010	9,164.756	9,076.706
2011	9,616.615	9,535.194
2012	9,424.615	9,407.078
2013	10,941.095	9,835.169

Source: IBGE and MAPA, 2015.

The sugarcane production in Brazil in the 2014/2015 season reached 630 million tons of sugarcane, of which 575 million tons were grown in the South Central region, 48 million tons in the Northeast and 7 tons in the North (MAPA, 2015). From this amount were produced 35 million tons of sugar and 29 million cubic meters of ethanol. The State of Sao Paulo, located in the South Central region of the country, accounts for 60% of total production of sugarcane in Brazil.

World planted area and production

The total area cultivated with sugarcane in the world increased from 20,517.5 million hectares in 2002 to 26,088.6 million hectares in 2012 (MAPA, 2015; FAO, 2015). During this period, Brazil took first place among the main producing countries with total area of 8,485.0 million hectares, followed by India (5,090.0 million hectares), China (1,802,700.0 million hectares) and Thailand (1,300.0 million hectares) in 2012 (MAPA, 2015).

Worldwide sugarcane production reached 1.8 billion tons in 2012. From that amount, Brazil reached 594 million tons, followed by India (348 mi t) and China (134 mi t) (Table 2) (MAPA, 2015; FAO, 2015).

Table 2: Production of main sugarcane producing countries, in million tons.

Country	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Brazil	349.6	374.7	382.3	428.3	495.5	552.8	622.6	627.3	565.8	594.3
India	287.4	233.9	237.1	281.2	355.5	348.2	285	292.3	342.4	347.9
China	90.2	89.8	86.6	92.6	113	124.2	115.6	110.8	114.4	123.5
Tailand	74.3	65	49.6	47.7	64.4	73.5	66.8	68.8	96	96.5
Pakistan	52.1	53.8	47.2	44.7	54.7	63.9	50	49.4	55.3	58.4
Mexico	47.5	48.7	51.6	50.7	52.1	51.1	49.5	50.4	49.7	50.9
Philippines	31	33.5	31.4	31.6	32	34	32.5	28	30	30
USA	33.9	29	26.6	29.8	27.8	25	27.6	24.8	26.7	27.9
Australia	37	37	37.8	37.1	36.4	32.6	30.3	31.5	25.2	26
Argentina	22.1	20.9	24.4	26.5	24	27	27	26	27	25
Indonesia	24.5	26.8	29.3	29.2	25.2	25.6	26.4	26.6	24	26.3
Colombia	39	40	39.8	38.5	38.5	38.5	43	37	42	38
Guatemala	17.4	20	18	17.6	20.3	20.3	21.5	22.3	20.6	21.8
Vietnam	16.9	15.6	14.9	16.7	17.4	16.1	15.6	16.2	17.5	19
South Africa	20.4	19.1	21.3	20.3	19.7	19.3	18.7	16	16.8	17.3
Egypt	16.2	16.2	16.3	16.7	17	16.5	15.5	15.7	15.8	16.5
World	**1378.6**	**1340.9**	**1316.4**	**1421.9**	**1618.5**	**1753 5**	**1693.5**	**1707.9**	**1819.4**	**1832.5**

Source: FAO (2015); MAPA (2015).

3. Technological evolution in cultivation and productivity

The sugarcane crop has great importance in Brazilian agribusiness, with current area and increase crushing capacity by deploying new technologies in operations, encompassing changes in planting and harvesting, generating large increase in the production of bioenergy, technological advancement and discovery of new products such as biobutanol, cellulosic ethanol and bioplastics, causing major changes in industry structure (VIANA and PEREZ, 2013).

The main advance in sugarcane production system in Brazil was the elimination of burn before harvest. The harvesting system without burning or mechanical harvesting leaves the straw over the soil surface, which have advantages such as soil protection against erosion and water loss, as well as increased carbon accumulation in the soil (LEAL et al., 2013).

New technologies such as no tillage and manure application have been also incorporated. The no-tillage system compared to the conventional system has increased productivity and better soil conservation (DUARTE JUNIOR, 2008).

The use of vinasse provides higher concentrations of potassium in the soil, increasing the potential productivity especially in sandy soil. The filter cake provides better soil fertility by providing macronutrients and micronutrients, lower levels of aluminum, by acting as a corrective of acidity, providing higher levels of phosphorus and nitrogen in the shoot. Besides the possibility to be used together to fertilization and enhance the results on productivity and decrease costs.

Another developing technology is the planting of pre-sprouted seedlings, in order to reduce the amount of cane-bullets used during field establishment, as well as improve control of diseases. Changes in planting spacing has also been evaluated, such as planting alternating double-rows (1.5 x 0.9 m) that allows controlled traffic, reduction in row compaction and thus increases in yield and longevity.

The removal of straw from fields for energy or second-generation ethanol production is in full expansion in many producing regions of sugarcane in Brazil. However, despite the economic appeal of this practice, sustainability issues need to be clarified, given the positive effect of straw in maintaining soil moisture, increases C and N stocks and sugarcane productivity, especially in regions subjected to high temperatures and limited rainfall.

4. Employment in sugarcane production system

Historically, the Brazilian sugarcane industry was associated with poor working conditions, especially for manual harvesting of sugarcane. Currently, with the advancement of mechanized harvest, which has already reached 85% of the cultivated area in the South Central region, working conditions have improved significantly.

However, there is a concern related to the unemployment that may be caused by mechanization. In this view, despite the reduction in job position caused by mechanization, there has been observed an increase in demand of better-qualified handwork. The mechanization process is creating opportunities for tractor drivers, truck drivers, mechanics, harvesters’ drivers, electronics technicians, among others, and thus reducing the demand for low qualified handwork (MORAES, 2006).

The economic development of the regions varies due to different local or national actions, which could determine growth rates and can generate socio-economic inequality between regions. Some regions have maybe advantages in structure and higher productivity, favoring the development of the sugar and ethanol industry and creating jobs (SOUSA, 2013).

5. Strategies to increase productivity and sustainability

Brazil has large area available for planting sugarcane, without causing damage to the production of other foods, as well as having production structure and distribution of technology products. The country reaches the whole cycle of ethanol production, beginning in fields with high yields to installation of equipment for the providers of this biofuel industry (MAPA, 2014).

Sugarcane expansion areas often take the place of degraded areas with grains or pastures due to economic reasons, i.e. the availability of areas with low production efficiency transformed into productive areas with sugarcane cultivation. Little progress occurs on native vegetation area, and for recovery of degraded pasture, areas can be used soybean planting by one or more years to improve the soil for implementation of the sugarcane crop (MACEDO e SEABRA, 2008).

In order to guide the sustainable expansion of sugarcane in Brazil, the federal government launched a political based on environmental, economic and social criteria. The Agro-Ecological Zoning of Sugarcane defined areas suitable for planting the crop considering climate types, soil, biomass, land slope, need of irrigation, among others characteristics (MAPA, 2014). The study revealed an available area to expansion of sugarcane or other crops up to 65 million hectares, without the need of causing deforestation or advancing in protected areas such as Amazon or Pantanal.

The increased productivity of sugarcane comes from the improvement of varieties, plant protection treatments, changes in cultural practices, correct use of fertilizers, choice of regions with favorable climate and soil production, better control of weeds, pests and diseases.

Green energy from sugarcane

The production of ethanol from sugarcane in Brazil is a model that is well accepted because it renewable and form biomass stocks for which the world has more sustainable agricultural production. The recent growth of the sugarcane industry is basically due to the development of new technologies for the production of bi-fuel vehicles or flex fuel capable of use both ethanol and gasoline or even a mixture of both. The final aim is to increase the use of clean energy sources in order to reduce carbon monoxide emissions to meet the requirements of the Kyoto Protocol (SOUZA e MIZIARA, 2010).

Internally in Brazil, sugarcane mills signed the “Environmental Protocol of the Sugarcane Sector" in order to conserve soil and water resources, protecting forests, recover river basins, reduce the emission of greenhouse gases and increase the efficiency of fertilizer use and agrochemicals products (AMARAL et al., 2008). Reducing water in the industrial process is a requirement for sustainable ethanol production. Re-use of water in a closed circuit in the processing stage can reduce 90% of water usage (SALAZAR, et al., 2013).

The cogeneration of energy has been an option for sugar and alcohol companies, due to the oscillation of energy production by hydropower and the variation in rainfall, so the cogeneration is a safe, cheap and environmental friendly option (CARDOSO, 2011).

Competition for bagasse for energy generation, genetic and physiological improvement of sugarcane, and requirement for pre-hydrolysis of bagasse are variables that can affect the second-generation ethanol (RAELE et al., 2013).

Different levels of integration between first and second-generation ethanol are possible, using technologies for hydrolysis and fermentation of pentoses, resulting in great benefits due to higher ethanol production and better economic results. Ethanol of second-generation has higher production per ton of cane processed, between 200 and 400 liters per ton of dry matter in the fermentation and degradation of pentoses (DIAS et al., 2012 a, b).

According Deshmukh et al. (2013) the integrated system based on the use of biomass and combined cycle gasification used in sugar mill provides better generation and power exportation than the direct consumption of bagasse combustion in the high-pressure steam cycle, which is beginning to be used in the sugar industry.

The increased volume of bagasse in the last few years represents 19.3% of Brazil's energy matrix in 2010, and all renewable energy sources accounted for 47.6%, while in the global scale renewable sources reached approximately 15.6% (HOFSETZ and SILVA, 2012).

Byproducts of the sugar and ethanol manufacturing process

In the sugar and ethanol production process, the byproducts generated are reused in the industrial or agricultural processes, reducing production costs and environmental impacts. Bagasse is a fibrous residue from the extraction of the juice by the mills and the amount produced depends on the processed sugarcane fiber. Bagasse can be used as a source of fuel (energy) for boiler, pulp production and cattle confined feed.

Filter cake (or press mud) is a byproduct generated mainly in the production of sugar, in rates varying from 5 to 30 kg t^{-1} of sugarcane processed depending on the extraction process of the juice. It contains around 75% of humidity and composting process have been adopted to reduce humidity, dosages and quality of application to the fields. Filter cake is applied to the fields as source of organic matter, phosphorus, nitrogen, calcium, sulfur and other nutrients, in planting or to the ratoon, in rates varying from 5 to 20 t ha^{-1} of dry matter.

The vinasse is the main byproduct of ethanol production. It is produced at a rate of 13L per 1L of ethanol produced and presents considerable amounts of potassium. This liquid byproduct is applied to sugarcane in the form of irrigation, supplying the whole amount of potassium required by sugarcane, as well as a portion of sulfur and nitrogen. Environmental legislation has advanced greatly in recent years and, currently, the industrial plants must draw up a vinasse implementation plan to be submitted annually to the environmental agencies to permit the milling. One strategy to adjust the vinasse application to environmental requirements refers to the concentration of vinasse. Equipments are available in Brazil for installation annexed to the mills, allowing concentration between 8-10 times the vinasse. In this system, the dosages normally used of conventional vinasse (between 60-150 m^3 per year) are reduced to 6-12 m^3 ha^{-1} per year, with operational, economic and environmental advantages.

Animal feed

The livestock activity is expensive and the productive sector seeks lower cost of alternative food sources. Grinding sugarcane for feeding is an interesting strategy, since the sugarcane production coincides with the period of lowest forage production (winter), when a loss of weight of animals is often observed (MURTA et al.; 2011). The sugarcane can also be used as silage, usually available in feedlots, being effective as forage for beef cattle. Cattle farmers have sought alternatives to reduce their production costs with feeding, since the confinement is a high-risk economic activity (PINTO et al., 2010).

The sugarcane bagasse as form of animal feed can be implemented with the use of treatments to improve digestibility, as alkalizing agents that can been used for hydrolysis (MURTA et al., 2011). Another technique that can be used is the ammonization of bagasse with urea to improve nutritional characteristics, by increasing the digestibility of fiber and crude protein content (PIRES et al., 2004).

Final remarks

The area planted with sugarcane is expanding rapidly in Brazil, but without advancing in areas of native forest or protected areas. The sugarcane is a renewable alternative to the production of sugar, ethanol and electricity. Second-generation ethanol requires further development, in order to allow ethanol production trough enzymatic hydrolysis of bagasse or straw.

Brazil is the largest producer of sugarcane of the world and better farming practices are being developed to increase productivity. These include mechanical harvesting without burning, mechanical planting, soil amendments and fertilization practices, changes in the form of planting and the development of varieties adapted to the soil and climate of the expansion areas. Increased mechanization of planting and harvesting has offset the reduction of jobs by increasing requirements of qualified handwork. The mechanization of harvest process reduced historical problems of labor relations and improved social aspects of biofuel production in Brazil.

It is necessary an International Public Political to expand the planted area in the world, making it a commodity to meet the global energy demand. Brazil, for its technical and scientific knowledge of the production chain, can contribute to the diffusion of agricultural and industrial technology needed for high productivity in a variety of soil and climate environments, to significantly advancing in sustainable energy production.

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B.3. ECONOMIC EVALUATION OF SHORT-ROTATION EUCALYPTUS PLANTATION HARVESTING SYSTEM: A CASE STUDY

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Introduction

In some European and American countries, the use of modified forager machines for forest harvesting has been the target of studies since the 90s. Some researchers like Mitchell et al. [1], Spinelli & Magagnotti [2], Schweier & Becker [3-4] and Eisenbies et al. [5] analysed the operating performance of available forage harvesters in the market from the following brands; Jaguar, Class, John Deere, and New Holland. In these studies the main trees genres used were poplar (*Poplar* spp.) and willow (*Salix* spp.). Modified foragers have the characteristic of transforming the entire tree into small fragments of wood, known as wood chips. These wood chips can be burned and generate renewable energy.

In Brazil, Eucalyptus is a promising gender for renewable energy production in short rotation coppice (SRC) [6]. According to Guerra et al. [7], short-rotation Eucalyptus plantations may present superior biomass production in shorter time, when compared with the conventional forestry, reaching 120 m^3 ha^{-1} in just one year.

Short rotation coppice systems are design to increase the population density resulting in high quantity of low-priced final biomass product [8]. In addition, as a fast growth species, Eucalyptus cultivated in SRC, system characterized by constant removal of biomass, requires an extra fertilization to maintain the soil fertility and high productivity rates [1]. So, this system demands highly efficient operations to active success, especially within harvesting, whereas its cost can account of 50% of total cost [8].

The introduction of modified forager machines in forest systems is quite recent in Brazil. A few years ago New Holland brought to the country a forager machine with the purpose of harvesting Eucalyptus plantations for bioenergy. Since then, there are still no records of studies regarding harvesting system with commercial tree species used in Brazil.

Thus, a case study was conducted to analyse the cost of a modified forager harvester and pulled-tractor silage trailer system in short-rotation Eucalyptus plantation in Brazil.

Material and Methods

The plantation harvested was a short-rotation Eucalyptus hybrid clone C219 (*Eucalyptus grandis* x *Eucalyptus urophylla*) of 1.7 ha located in Botucatu, Sao Paulo state. The plantation spacing had 3.0 x 1.0 m (3,333 plants ha^{-1}) and trees average base diameter (at 9 cm of height) was 10 cm and had 2.8 years at harvest time. The area maximum land slope was 6%.

Integrated the harvest system: a New Holland FR9060 self-propelled forager machine attached to New Holland 130FB coppice header, two New Holland TM7040 132 kW tractors and four TMA VTX 10,000 silage trailers (24 m^3 of capacity). This system´s cost analysis methodology was adapted from ASABE [9] and the costs obtained were determined in two units: cost per time and quantity harvested in oven-dry ton (odt).

Ownership costs or fixed costs (FC) consist of depreciation, interest on fixed assets and other costs (taxes, housing and insurance), which focus on all the equipment of the mechanized harvesting system (harvester, tractor, and silage trailer) and are detailed in the equation:

$$FC = \left\{ \left[\frac{V_i + V_f}{2} \times i \right] + \left[\frac{V_i - V_f}{EL} \right] + [THI] \right\} \times \frac{1}{pmh}$$

Where:

FC = fixed cost (€ $hour^{-1}$)

V_i = acquisition value of machinery and equipment(€)

V_f = final value of machinery and equipment (€)

i = interest rate per year (%)

EL = economic life (years)

THI = taxes, housing and insurance (% of V_i in € $year^{-1}$)

pmh = productive machine hours per year

Operating costs or variable costs (VC) consist of fuel, oil and lubricants, repairs and maintenances, and labor focusing on forage machines and tractors. The average fuel consumption is based on the actual power that is required or on the actual consumption measured in the field. Harvester average fuel consumption data were collected using the machine's on-board computer (*Intelliview*). To collect the tractor’s hourly consumption we followed the methodology described by Fiorese et al. [10]. To calculate oil lubricants and greases costs, we used the 15% factor in the cost of fuel.

According to ASABE [11], the accumulated costs of repairs and maintenance to a typical field velocity can be determined with the following expression using the repair and maintenance factors RF1 and RF2:

$$CRM = (RF1)P\left[\frac{h}{1000}\right]^{RF2} \times \frac{1}{a}$$

CRM = accumulated cost of repair and maintenance (€)

RF1 and RF2 = repair and maintenance factor

P = equipment price (€)

h = hours accumulated

a = area (ha)

Labor cost was estimated based on the monthly wage and work hours, including a correction factor of 25% due to idle time, in other words, time taken for repairs and supply of machines. Cost spend with employees transportation to the workstation were discarded. One workday consisted by two shifts of four hours each. Wages and labor charges were estimated based on the database provided by the forestry companies' partners.

Some harvester data were estimated because the product is not considered a commercial machine in Brazil. Prices were acquired in Brazilian reais (R$) but converted to euros (€) using the average exchange rate for 2015 of R$ 3.16 €$^{-1}$ according to the official website of the Central Bank of Brazil (www.bcb.gov.br). Only fixed costs were used to silage trailer (Table 1).

Table 1. Input parameter for cost calculation

Description		**Harvester**[a]	**Tractor**	**Silage**
Estimated purchase price	€	316,500.00	55,380.00	28,500.00
Expected economic life	years	7	9	12
Annual use	pmh[b]	600	1,500	n.a.
Residual value	%	10.00	10.00	10.00
Interest rate	%	5.00[c]	5.00	5.00
Housing	%	0.75	0.75	0.75
Insurance	%	0.25	0.25	0.25
Fuel consumption	L h^{-1}	80	25	n.a.
Fuel price	€ L^{-1}	0.80	0.80	n.a.
Repair factor 1		0.03	0.003	n.a.
Repair factor 2		2.0	2.0	n.a
Operator wage	€ $month^{-1}$	633.00	633.00	n.a
Labor charges	%	125.00	125.00	n.a

Note: [a] FR9060 and 130FB, [b] pmh = productive machine hours, [c] KTBL [12], n.a = not applicable

To estimate the cost per ton harvested we used the effective field productivity (EFP) which was calculated as shown:

$$EFP = \frac{d \times s}{10000 \times t} \times \frac{1}{OY}$$

Where:

EFP = effective field productivity (odt h^{-1})

d = distance (m)

s = space between rows (m)

t = time (h)

OY = operating yield (t h^{-1})

EFP result was expressed as oven-dry tons (odt) per hour since wood chips are produced from standing trees with an average moisture content of 52%.

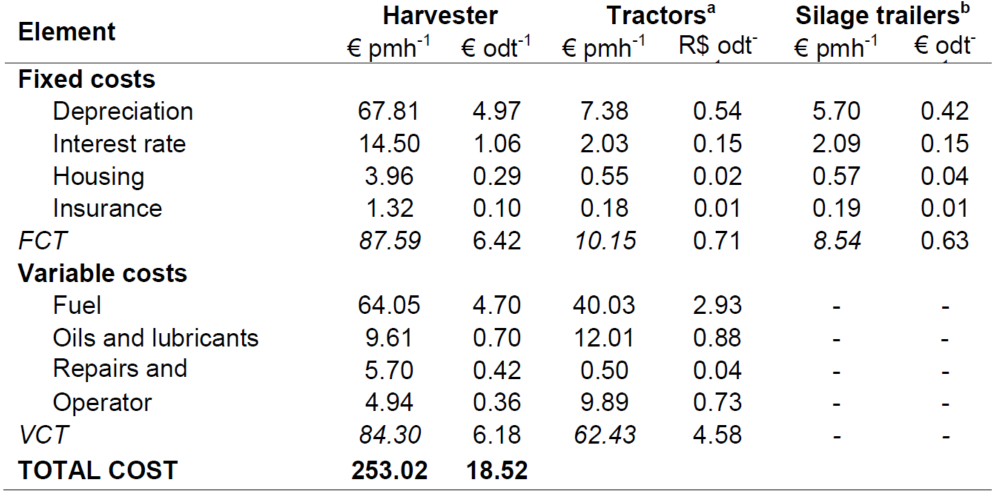
Results and Discussion

Productivity and EFP were 0.44 ha $h^{-1}$and 31.0 odt h^{-1}, respectively. Using the same forage machine in a SRC poplar in Germany, a productivity average of 0.90 ha h^{-1} and a EFP of 14.6 odt h^{-1} were obtained [4]. Tests conducted in the United States, harvesting willow, showed results from 1.8 to 2.3 ha h^{-1} of productivity and a EFP between 23.9 and 24.9 odt h^{-1}, requiring speeds from 8.0 to 10.0 km h^{-1} in which is unrealistic regarding a SRC [5]. These studies were conducted in temperate regions where the most common source of raw material are Salix spp. and Poplar spp. Plantations. These species are generaly harvested around 3 and 4 years, and the basic wood density average is 350 and 410 kg m^{-3}, respectively [13]. Eucalyptus spp. has a average basic wood density of 430 kg m^{-3} [14]. This information might justify the result of higher EFP in Brazil, once Eucalyptus´s wood density is 4.6% and 18.6% higher than willow and poplar, respectively.

The harvester productivity per area is related to the working speed in which could be limited by terrain conditions (i.e slope and soil type), planting condition (i.e trees diameter, planting spacing and presence of old stumps between planting lines), operator experience level, and forage harvester power.

The harvest system´s total operational cost was € 253 pmh-1 or € 18.5 odt-1 being the harvester the largest contributor of total cost with fixed cost total of € 87 pmh-1 and € 6.4 odt-1 (Table 2).

Table 2. Operational costs



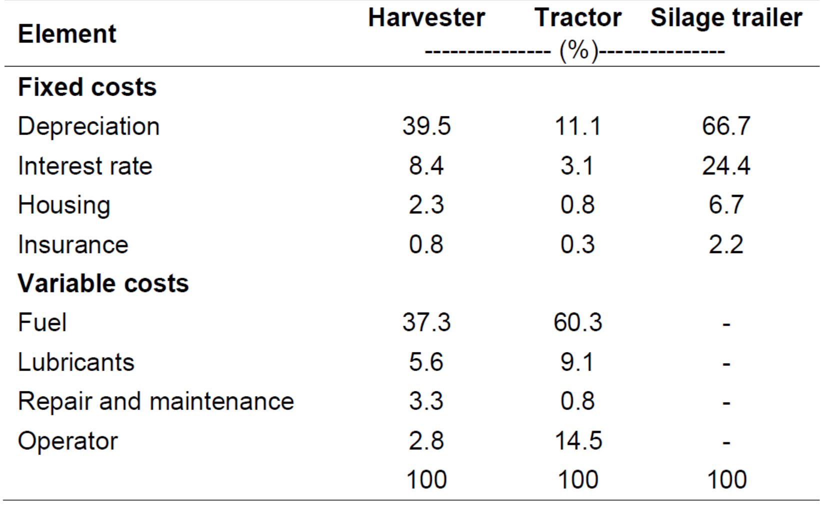
Element	Harvester		Tractors^a		Silage trailers^b	
	€ pmh^{-1}	€ odt^{-1}	€ pmh^{-1}	R$ odt^{-}	€ pmh^{-1}	€ odt^{-}
Fixed costs						
Depreciation	67.81	4.97	7.38	0.54	5.70	0.42
Interest rate	14.50	1.06	2.03	0.15	2.09	0.15
Housing	3.96	0.29	0.55	0.02	0.57	0.04
Insurance	1.32	0.10	0.18	0.01	0.19	0.01
FCT	*87.59*	6.42	*10.15*	0.71	*8.54*	0.63
Variable costs						
Fuel	64.05	4.70	40.03	2.93	-	-
Oils and lubricants	9.61	0.70	12.01	0.88	-	-
Repairs and	5.70	0.42	0.50	0.04	-	-
Operator	4.94	0.36	9.89	0.73	-	-
VCT	*84.30*	6.18	*62.43*	4.58	-	-
TOTAL COST	**253.02**	**18.52**				

Note: FCT = fixed costs total, VCT = variable costs total / Exchange rate (average price of 2015): € 1.00 = R$ 3.16 / a two tractors, b four silage trailers

Schweier & Becker [4] determined an estimated a total cost of € 281 h^{-1} and € 19.70 odt^{-1}. The harvester per unit time individual cost (excluding labor costs) was found by Berhongaray et al. [15], which was 212.5 € h^{-1}. Despite the high value of labor charges on the operator's wage and the rise of the exchange rate, operational costs are below those found in the literature. This difference is even greater due to the mean annual increment (MAI) of Eucalyptus in SRC and its impact on the EFP generated by the harvester in this system.

The percentage contributions to total cost of each equipment item are listed in table 3.

Table 3. Participation of each element on the individual cost



Element	Harvester	Tractor	Silage trailer
	---------------	(%)	---------------
Fixed costs			
Depreciation	39.5	11.1	66.7
Interest rate	8.4	3.1	24.4
Housing	2.3	0.8	6.7
Insurance	0.8	0.3	2.2
Variable costs			
Fuel	37.3	60.3	-
Lubricants	5.6	9.1	-
Repair and maintenance	3.3	0.8	-
Operator	2.8	14.5	-
	100	100	100

Depreciation and fuel are two factors that most contributed to the total cost of the harvester, justified by the high purchase price high fuel consumption of this equipment. Operator's experience can be crucial to reduce fuel consumption because it is necessary to adjust the speed according to the forest conditions in order to increase wood chips production while manage operational time and fuel consumption efficiently, without wasting trees and preserving both sets of base cutting disks and cutting knives.

Whereas this forager harvester is non-commercial equipment, lifespan and productive annual hours were estimated, thus, with the adaptations improvement for Brazilian forests conditions both parameters can be even greater reducing the depreciation cost of the harvester.

The greater part of the tractor cost is related to the consumed diesel and here, again, the experience of the operator is decisive. Proper engine rotation for each harvest stage, proper adjustment of ballast weights, the type of tires and their internal calibration are factors that significantly influence the tractor's performance [16-17-18].

Suitable fleet sizing is essential to reduce idle time in the harvesting process; however, this analysis demands full time studies and measurement of the maximum distance between harvested area and wood chip discharge area in order to optimize the logistics. In this assessment, the required fleet sizing was estimated from authors' experience.

Once the produced biomass will be for bioenergy production, the calorific value contained in this material becomes relevant. Guerra et al. [7] conducted a study testing the same clone in order to quantify the calorific value of a SRC under different spacing and fertilization levels. At 2 years old, in 2.8 x 1.0 m spacing (3,571 plants ha^{-1}) and applying the conventional fertilization dose, this clone reached an average of 20 GJ t^{-1} or 761 GJ ha^{-1}. Converting to megawatt-hour, a productive day of harvesting would be able to produce around 2,500 GWh. This energy is sufficient to generate electricity during three hours in a European city with 542,000 households [19], or 16 hours in a large Brazilian city with 2,000,000 inhabitants [20]. Clearly, this comparison is both informative and illustrative because it does not include generation neither transmission loss of energy, among other factors.

Conclusion

The use of modified forage machines for harvesting Eucalyptus in SRC, despite harvesting a smaller area per time, could reach a greater amount of harvested material per area compared to consolidated harvesting systems for willow and poplar plantations in temperate countries due to the difference of the wood basic density.

Even with high labor charges values and high exchange rates, the total estimated cost is cheaper than those from temperate countries, with depreciation and fuel consumption being the biggest influences of total cost. The experience level of the harvester and tractor operators is crucial to this system economy.

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SESSION C: APPLICATIONS

C.1. COMPARISON OF CORN STALK, SOYBEAN STEM AND WHEAT STRAW FIBRES IN POLYPROPYLENE COMPOSITES

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Abstract

Natural fibre composites are emerging as a viable alternatives to mineral, carbon and glass-reinforced composites for manufacturing automotive parts, construction materials, and for electrical and electronic uses because of their low cost, as well as their ecological and performance benefits. The global natural fibre composite market is expected to grow by 12% annually with an expected value of $5.8 billion (US) by 2019. The growth in automotive industry and construction; promulgation of new environmental regulations; local availability of natural fibres; the suitability of natural fibres to various manufacturing processes (including compression and injection moulding); and consumer acceptance of bio-filled composite materials are some of the key drivers for the natural fibre composite market expansion (http://www.researchandmarkets.com/reports/2881528/global-natural-fiber-composites-market-2014-2019; accessed on May 21, 2015). Polypropylene reinforced with natural fibres is a model for bio-filled thermoplastic composite for manufacturing.

Ontario is one of the largest agricultural biomass producing provinces in Canada. Ontario and its neighbouring Michigan state of USA host more than 95% of the automotive industry in the North America. The majority (~ 80%) of approximately 3.12 million tonnes of sustainable agricultural plant residue produced annually in Ontario comes from corn and wheat (Oo and Lalonde 2012). Corn can produce 2.07 tonnes of residue per acre, alone. This crop was grown on 1.86 million acres in Ontario in 2014 (http://www.omafra.gov.on.ca/english/stats/crops/estimate_new.htm; accessed on May 21, 2015). Corn also produces two different types of fibres, obtained from the stalks and cobs. Local corn fibre is an abundant source of renewable and biodegradable natural fiber. However, the influence of corn genotype and environment on the functional properties of the fibres once incorporated into composites is unknown. This study was initiated to investigate the influence(s) of plant genotype and environment on the performance characteristics of composite materials produced with fibres extracted from various agricultural residues, in particular corn stalks and cobs.

Forty corn recombinant inbred lines (RILs) based on phenolic compounds including esterified ferulic acid (EFA), dehydrodimers of ferulic acid (DFA) and *p*-coumaric acid (PCA) in the kernels were selected from a total of 144 lines of a cross CG62 x CO387. The selected lines along with their parents

were grown in the four Ontario environments. At maturity five plants were randomly selected for fibres. Dried stalks and cobs were grinded with a Thomas Wiley Mill Model 4 (Thomas Scientific, Swedesboro, NJ, USA) to pass through a 2 mm sieve in the stage I of the study. In stage II the materials were ground and selected with a 2 mm sieve. Prior to composite processing and testing, all corn fibre samples were chemically analysed for cellulose, hemicellulose, lignin, total free phenolic, *p*-coumaric and ferulic acids. Fibre particle size, moisture content and thermal stabilities were determined before compounding in the polypropylene (PP) matrix.

The fibre's thermal properties including thermal stability and onset degradation temperatures (°C) were measured by heating 5 to 10 mg samples from 35 °C to 700 °C at a rate of 20 °C min^{-1} under nitrogen at a flow rate of 50 mL min^{-1} using TA Instrument Q500 TGA Model 19720 (TA Instruments, New Castle, DE, USA). TGA thermographs were used to measure fibre weight loss for RILs. Onset degradation temperatures (°C) were recorded as the temperatures (°C) after 150 °C at which the sample showed 1% weight loss. The moisture content of the corn stalk fibres (4.1 ± 0.2 percent) was determined prior to incorporating them into the composites. Homopolymer polypropylene (PP), grade D180M (Sunoco chemicals, Inc., Philadelphia, Braskem America) with 18 melt flow index (MFI) was used for corn fibre composites studies. Fusabond P-353, Maleic anhydride grafted (Dupont, Canada) was used as coupling agent. Antioxidants Irganox 1010, Phenolic and Irgaphos 168, Phosphate (Ciba, Inc., Canada) were also used in the compounding process.

Compounding was done to get homogeneous material through melt blend process. Corn stalk residue (20 wt-%), polypropylene (77.5 and 67 wt-% in stage I and II respectively), coupling agent (2 wt- %) and antioxidants (0.25 wt-% each) were blended together using a conical twin-screw micro-extruder (Haake Manilab, Thermo Electron Corporation, Canada) with processing conditions of 190 °C and 40 rpm machine speed. Five test specimens were injection moulded according to ASTM standards using the injection moulding machine RR/TSMP (Ray-Ran, Warwickshire, UK) with the barrel temperature at 190 °C, mould tool temperature at 50 °C, 15 sec hold time at 100 psi. The test specimens were annealed in air circulating oven GC 5890A (Hewlett Packard, USA) at 151°C for 11 min and then cooled down to room temperature at a rate of 10 °C/minute. Five test specimen bars as described by ASTM methods D790-10 and D256-10 for flexural and impact and five test bars as described by ASTM method D1708-10 for tensile properties were used to measure the physical properties of the corn fibre pp composites.

Chemical analysis showed significant variation among the corn fibres for cellulose, hemicellulose, lignin, total free phenolics, *p*-coumaric and ferulic acids quantities. Environments affected the chemical composition of the fibres significantly. In stage I of the study, a total of 336 corn stalk and cob fibres polypropylene composite samples were tested for physical properties including flexural strength, flexural modulus, tensile strength, tensile modulus and impact strength. The corn fibre PP composites were significantly different for physical properties from each other and also from pure PP. Environments where the fibres were grown had significant effects on the composite properties. The corn stalks fibres improved flexural strengths (24%), flexural moduli (58%), tensile strengths (7%), and tensile moduli (24%). However, impact strengths were reduced up to 21%, compared to pure PP. The corn cobs improved flexural strength (17%), flexural moduli (38%) and tensile moduli (1%). However, tensile and impact strengths were reduced up to 9% and 6%, respectively, compared to pure PP. Based on stage I results, two corn stalk samples (genotype 37 and 122) out of 336 were selected for scale-up composite production and comparative studies with soybean stem and wheat straw fibre PP composites.

Corn stalk, soybean and wheat straw fibres were produced in a commercial facility (OMTEC Inc., a commercial natural fibre processor) located in Ridgetown, Ontario. Composites with 30% (wt/wt) fibre of were compounded in a PP matrix in stage II of the project. The corn stalk fibre PP composites showed substantial increases in flexural strength (30 – 31%) and flexural modulus (75 – 83%), without significant losses in impact strength (-0.9 & -2.3%) for both corn genotype-37 and 122 fibres, respectively, compared to pure PP (Figure 1). Also, some losses in tensile strengths (-14 & -22%) and tensile moduli (-8 & -16%) were observed for both genotypes. The corn stalk PP composites were also compared to soybean and wheat straw composites developed in a similar way as corn stalk fibre composites. Flexural strengths were 43, 59, 54, 56 and 55 MPa; flexural moduli 1087, 2276, 1933, 1991 and 1953 MPa; tensile strengths 34, 31, 33, 27, 30 MPA; tensile moduli 316, 309, 325, 265, 292; and impact strengths were 22, 25, 24, 22 and 22 for pure PP, wheat, soybean, corn genotype-37 and genotype-122, respectively. Generally, con stalk fibre composites were similar to wheat straw PP composites in their physical properties. Wheat straw reinforced PP composites are being used commercially in passenger bins inside the Ford Flex cabins. Both corn genotypes had fibres with similar physical properties. However, genotype-122 gave fibres that were stable in both stages of this study. These results indicate that this genotype has the potential for scale-up corn fibre/ PP composite production. This study also confirmed that plant genetics and environment play significant roles in fibre composition and their composite properties. Standardization of the fibre quality is necessary prior to commercial scale composite manufacturing.

The effect of increasing corn stalk fibre amounts from 20% wt/wt to 30%wt/wt in the composites had significant effects on their composite properties. For example, 30% corn stalk fibres composites had significantly higher flexural properties than 20% composites, without any negative effect on the impact strengths of the composites. However, tensile strengths and moduli were reduced in composites containing 30% fibre compared to 20% (Figure 2). To balance the physical properties of the composite PP with different molecular weights might be used. Generally, 10 to 20 MFI PP is an appropriate material for inside automotive cabin applications. This study revealed that PP (10 – 20 MFI) can be reinforced up to 30% corn stalk fibres without significant negative effects on the performance characteristics of the composites. Composites having higher than 30% fibre content might have improvements in some properties (eg flexural) but might also significantly reduce others characteristics (such as tensile strength and impact strength).

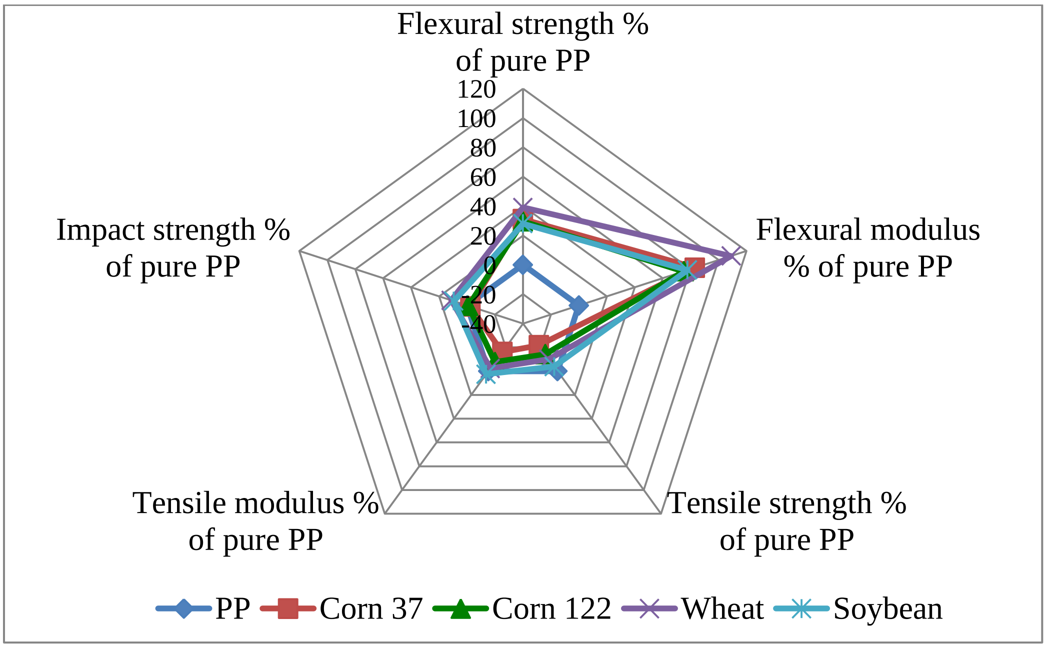

Figure 1. Corn stalk, wheat and soybean straw fibre PP composite properties shown as a percent of pure polypropylene

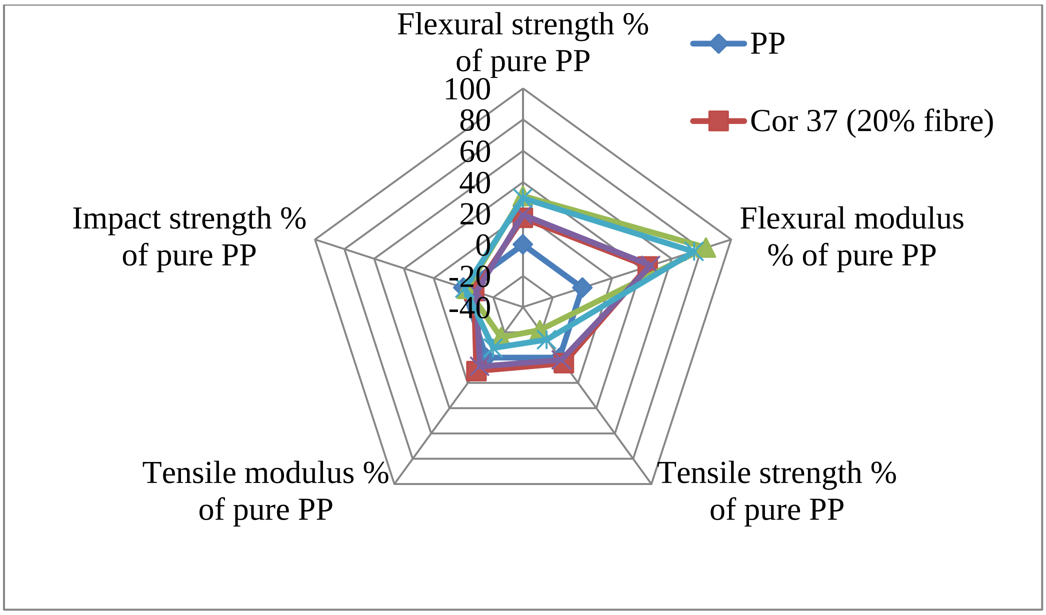

Figure 2. Corn stalk fibre/polypropylene composites contain different quantities of fibre affect their physical properties shown as a percent of pure polypropylene

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C.2. BIODEGRADABLE COMPOSITES MADE OF PHB AND POLYCARB(TM) FOR PACKING APPLICATIONS

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Abstract

The aim of the present study was to develop composites made of a blend of PHB (polyhydroxibutirate), Polycarb (modified starch) and a plasticizer agent from biofuel industry, glycerol.

The PHB was a standard grade supplied by the company Biocycle, Brazil. The Polycarb was supplied by the University of Toronto, Canada. The biofuel glycerol was a waste material obtained from the company Biopar, a Brazilian biodiesel producer. Several blends were made, ranging from 70 to 30% of PBH and 30 to 70 % Polycarb, respectively. Some of the treatments were made using biofuel glycerol at the rate of 46% by weight in relation to the Polycarb. The blends were produced using a twin screw extruder, Coperion 25 mm and later on injected for sample analysis (tension, flexural and impact resistance, surface hardness, folowing ASTM standards. The blends were evaluated for dimensional tests (dimensions, weight and thickness); mechanical properties (tension, flexural, impact resistance. The samples where tested for TGA AND DMA aiming to evaluate its performance for thermoforming applications (packaging trays).

1. Introduction

Nowadays there is an increasing trend in using natural polymers or biobased components in many composites for industrial applications, from packaging to automotive uses. First the production of bio-based thermoplastic composite-based products is more economical than the original thermoplastics. Second, as a result of environmental care politics, particularly important in countries where products result from agricultural sources, including starch and bioplastics offer an attractive and cheap alternative for developing biodegradable and renewable materials. Thermoplastic starch has become one of the most promising candidates among the various alternatives to substitute synthetic plastics, especially for packaging because it is an inexpensive material and behaves as a thermoplastic.

The glycerin is a very important waste material in the Brazilian biodiesel program, since its is produced at a rate of 10 m^3 for 90 m^3 of biodiesel produced in the conventional biodiesel plants using *transesterification* process. Considering that the Brazilian biodiesel program uses the B5 or 5% biodiesel added to the fossil diesel, the market is estimated to be 250,000 tons per year. The result is a production of glycerin much higher than the demand, estimated to be around 30,000 tons/year, and the prices dropped sharply. The prices had a reduction a 48% since 2005 and many companies are not interested in refining it. In 2005 the glycerin price was US$1.15 and now is lower than US$0.6 and in the production areas US$0.25. Many companies just want to reduce its stock since it is not their main focus. Therefore new uses for glycerin in Brazil are important.

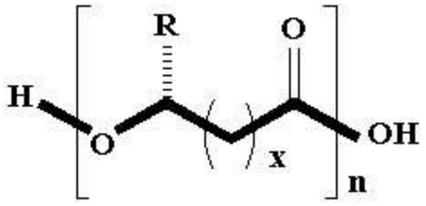
In recent years there has been considerable interest in the PHA family of biodegradable polyesters. These materials, produced by fermentation, occur as intracellular inclusions within the cytoplasm of many prokaryotic organisms. The most well-known PHA is poly(hydroxybutyrate) (PHB). The principal shortcomings of bacterial PHB that limit its usefulness as a thermoplastic material are its thermal instability and brittleness. For these reasons, there has been much interest recently in the preparation and characterization of blends based on PHB. Willett and Shogren (2002) reported on blends of starch and various thermoplastic resins to produce foams. The results showed that foams of cornstarch with PHBV had significantly lower densities and greater radial expansion ratios than the control starch. Zhang et al., 2006 studied blends of poly(3- hydroxybutyrate) (PHB) and starch acetate (SA), and found that the PHB/SA blends were immiscible. Melting temperatures of PHB in the blends showed some shift with an increase of SA content. Melting enthalpy of the PHB phase in the blend was close to the value for pure PHB. The glass transition temperatures of PHB in the blends remained constant at 91 ^{o}C. FTIR absorptions of hydroxyl groups of SA and carbonyl groups of PHB in the blends were found to be independent of the second component at 3470 and 1724 cm^{-1}, respectively.

Crystallization of PHB was affected by the addition of the SA component, both from the melt on cooling and from the glassy state on heating. Temperature and enthalpy of non-isothermal crystallization of PHB in the blends were much lower than those of pure PHB. Crystalline morphology of PHB crystallized from the melt under isothermal conditions varied with SA content. The cold crystallization peaks of PHB in the blends shifted to higher temperatures compared with that of pure PHB. Willett et al., 1998 utilized grafted copolymers of starch and glycidyl methacrylate (starch-g-PGMA) to improve the mechanical properties of composites with PHBV. In general, the tensile and flexural strengths of the composites were greater with starch-g-PGMA compared to untreated starch, and increased with increasing graft content. Grafting did not significantly change the modulus and elongation of these blends. All samples gained weight after immersion in water for 28 days. Tensile strength and modulus decreased with water sorption, while the fracture toughness significantly increased with grafted starch. SEMs of cryogenic fracture surfaces showed improved adhesion between the starch-g-PGMA and the PHBV matrix.

During the past decade, the environmental impact of plastic waste has been of global concern. Most plastic waste is incinerated or buried, but incineration may generate toxic air pollution (if not properly controlled) and landfill sites are limited. Also, petroleum resources are finite. Thus it becomes important to find polymers that are bio-based and biodegradable to substitute for conventional polymers, especially in short term packaging and disposable applications.

Bio-based polymers are polymers that are generated from renewable natural sources. They are often biodegradable. Biodegradable polymers are polymers that can be assimilated by micro-organisms, and thus introduced into the natural cycle. Biodegradable polymers can be classified into two groups: polymers coming from natural resources, such as starch, cellulose, polylactic acid and polyhydroxyalkanoates; and polymers synthesized from petroleum, such as polyesteramide and poly (vinyl alcohol). However, biodegradable polymers are not suitable for all applications, due to their poor durability and expensive manufacturing and composting process. Absorbable medical implantations, compostable bags for biowaste, compostable food packaging containers and agricultural mulch films are the major uses of biodegradable polymers Mayne et al., 2007.

Polyhydroxyalkanoates (PHAs) are a family of polyesters produced by bacterial fermentation with the potential to replace conventional polymers. They were first identified by the French microbiologist Maurice Lemoigne in 1926 (Lemoigne, 1926). High molecular weight polyhydroxyalkanoates are synthesized and stored in the cell cytoplasm as water insoluble inclusions by various microorganisms (Sudesh et al., 2000). Generally, PHA plastics are semicrystalline thermoplastics with the following generic structure (Chen, 2005) (Scheme 1).



Scheme 1: Structure of polyhydroxyalkanoates (PHA)

Radical “R” can be hydrogen or hydrocarbon chains of up to around C13 in length, and x can range from 1 to 3 or more. Varying x and R provides a broad range of physical and mechanical properties, such as hydrophobicity, glass transition temperature (Tg), melting point (Tm), and level of crystallinity which can range from around 70% to very low, giving excellent stiffness or elasticity as needed.

When R is a methyl group and x=1, the polymer is Polyhydroxybutyrate (PHB), which is the basic homopolymer in the PHA natural plastics family. PHB is made by a controlled bacterial fermentation and it can completely degrade to CO_2 and H_2O when attacked by various enzymes. PHB is a semi-crystalline material with a high melting temperature and a high degree of crystallinity. Its mechanical properties are comparable to those of isotactic polypropylene. However, PHB has a relatively high glass transition temperature which is near room temperature, and thus it is stiff and brittle at ambient temperature (Volova, 2004). At room temperature, the longer it is stored the more brittle it becomes, resulting from secondary crystallization at room temperature. It is 100% biodegradable but not soluble in water, and has the potential to be used in biodegradable packaging since its barrier properties are as good as PVC and PET. PHB is perfectly isotactic and does not include any chain branching and therefore it flows easily during processing.

High molecular weight PHAs are synthesized by various microorganisms and stored as water insoluble carbon and energy storage compounds in the cell Cytoplasm. Over 300 different bacteria have been reported to accumulate various PHAs. The different chemical structures of PHAs result in a wide range of physical properties, from stiff and brittle plastics to soft elastomers. The major problem of PHAs for commercial applications is the high cost of bacterial fermentation, making PHA polymers 5-10 times more expensive than petroleum based polymers. And thus synthesis of PHA in plants was carried out to lower the cost. PHB, which is the base homopolymer in PHA family, is highly crystalline with a melting temperature of about 180°C and a glass transition temperature of about 5°C (Chandra and Rustgi, 1998)

The combination of high crystallinity and low nucleation density of PHB results in large spherulites with cracks and splits, and thus makes the PHB products very brittle. Thus copolymers based on hydroxybutyrate monomer and other PHA monomers have been investigated. To date, the most widely studied PHB based copolymer is a copolymer of HB and hydroxyvalerate (HV), PHBV, which was marketed under the trade name —Biopoll by ICI Zeneca in UK (now is Metabolix in US). However, the fermentation process for producing copolymers of PHB is expensive. The thermal instability of PHB in the melt is one of the major drawbacks to commercial use of PHB. The chain scission process occurs in the thermal degradation of PHB according to a β-hydrogen elimination reaction. This type of degradation results in a gradual decrease in molecular weight. The basic problem with PHB is that the onset temperature of chain scission degradation is about 180°C, which is slightly higher than its melting temperature. In principle, the degradation might be avoided or limited either by reducing the melting temperature to lower the processing temperature, or by introducing some chemical groups to re-polymerize the thermally degraded polymer.

The physical ageing, attributed to the development of secondary crystallization and a progressive decrease of the amorphous content, causes an increase in yield stress and modulus and a decrease in elongation at break and fracture toughness. Due to the low crystallization rate, the interlamellar secondary crystallization of PHB occurs to form thin, small crystallites in the amorphous region during storage at room temperature. The presence of the small crystallites reduces the mobility of the chain segments thus embrittling the plastic. Effect of storage at room temperature on the tensile stress and strain of 8% HV copolymer. The secondary crystallization of the copolymer can be reduced by crystallizing the copolymer at high temperature, which leads to rejection of the HV units into the amorphous regions.

The main advantage of PHAs over other types of biodegradable polymers is that they can be completely degraded by microorganisms under aerobic and anaerobic conditions, such as soil, activated sludge and sea water (Sudesh, 2000). The end products of PHA degradation in aerobic conditions are CO_2 and water, while in the anaerobic conditions is methane. It has been found that the rate of biodegradation of PHA materials depends on many factors, including both those related to the environment (temperature, moisture level, pH and nutrient supply) and those related to the PHAs themselves (composition, crystallinity, additives and surface area). The life cycle of PHAs is illustrated in Scheme 2.

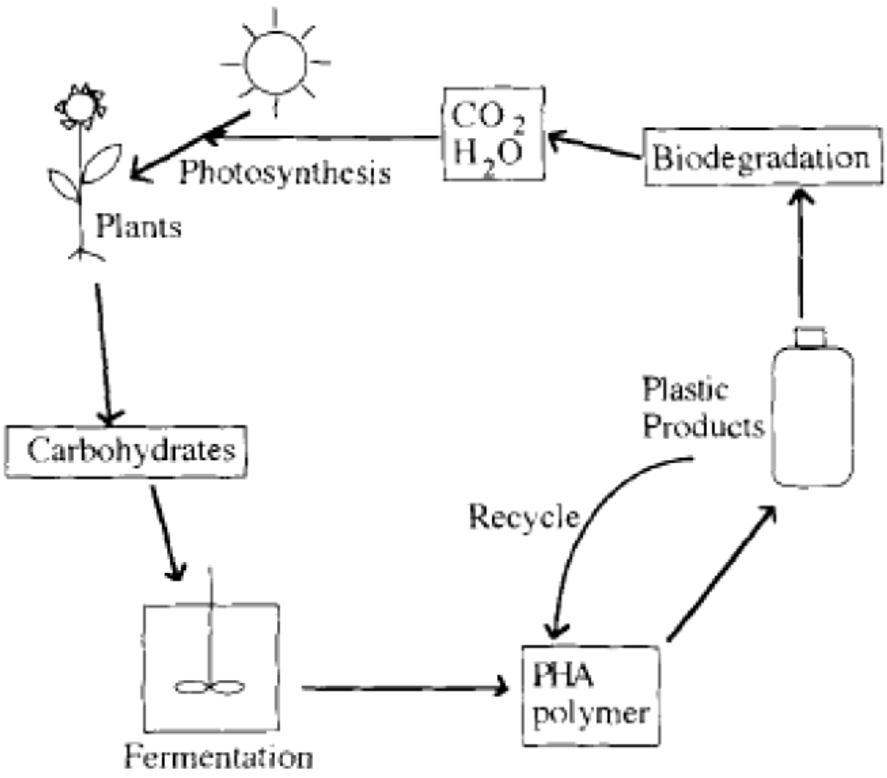
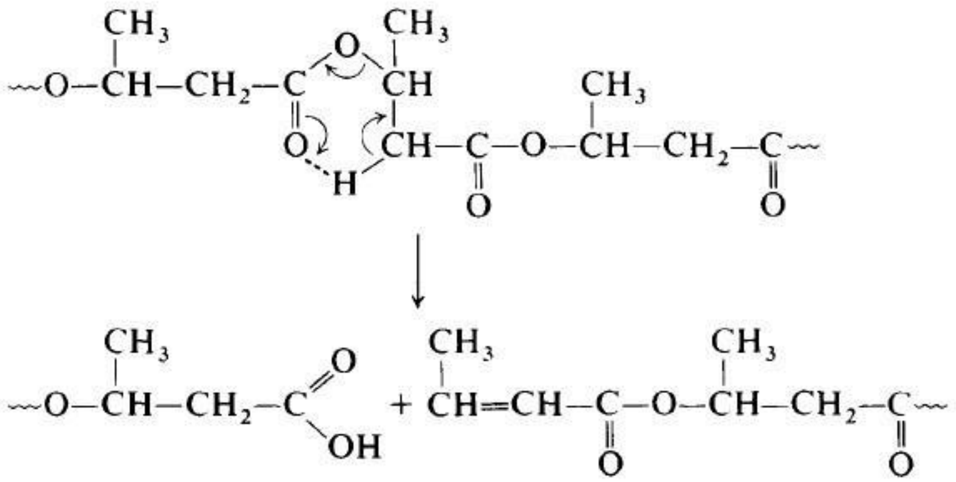


Figure 1: The life cycle of PHAs

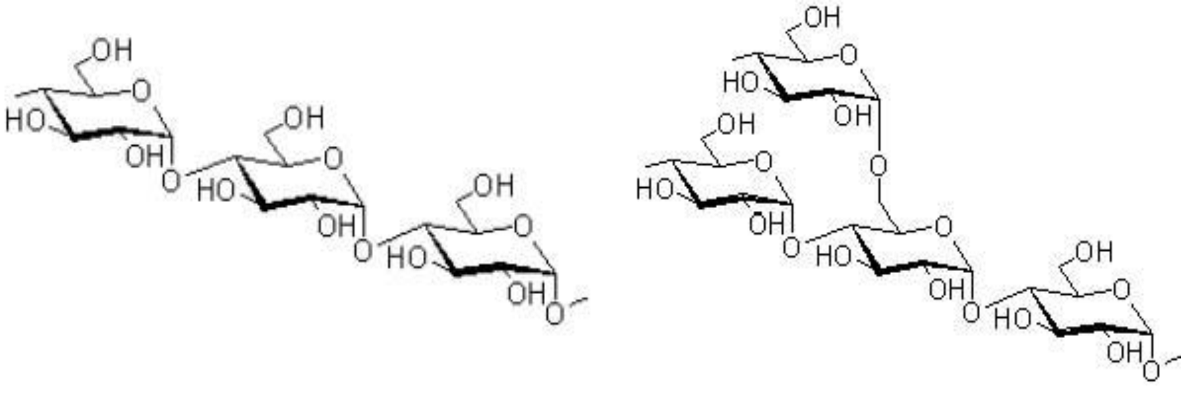
PHA polymers have been widely used in medical applications, such as drug delivery and surgical swabs, due to it being biocompatible and biodegradable. Commercial grades of PHA are Biopol PHBV, being developed by Metabolix, and Nodax PHA copolymer, marketed by Procter & Gamble (now licensed to Meridian). The products of PHBV under trade name of Biopol have been commercially used on the market. In 1990, the German hair-care company, Wella, marketed a shampoo bottle (SANARA) made from Biopol, but production was stopped due to the high cost. However, PHB has three main drawbacks:

1. The fermentation and extraction process is inefficient and expensive;
2. It has poor formability and mechanical properties. It is purer than the commercial polymers, i.e. it has a lower nucleation density, and thus it forms large spherulites with cracks and splits, which have a negative influence on the mechanical properties.
3. Its thermal decomposition temperature, 210°C, is just above melting temperature, 175°C, therefore leaving a narrow temperature window for processing. The degradation of PHB in a temperature range of 180°C to 200°C is due to the random chain scission, as shown in Scheme 2, causing a gradual decrease in molecular weight. The basic problem with PHB is that at its melting point its chain scission rate is too fast.



Scheme 2: A scheme of chain scission process in thermal degradation of PHB.

Several attempts have been made to improve the thermal and mechanical properties of PHB, such as addition of nucleating agents, which can reduce the size of the spherulitic crystals, to improve the mechanical properties. Another approach was to produce new copolymers, such as poly (hydroxybutyrateco-hydroxyvalerate) (PHBV), although such product is very expensive and the crystallization requires longer time, which leads to a longer cycle time for injection moulding. However, the most economical and commonly used method is to blend PHB with other polymers or additives. Examples are starch, cellulose and cellulose derivative, polylactic acid (PLA), polycaprolactone (PCL), poly(vinyl acetate) (PVAc), plasticizers and clay filler etc.



1. (b)

Scheme 3: (a) Structure of amylose and (b) structure of amylopectin

Starch is considered as an attractive biopolymer due to its low cost, low density, non-abrasive nature, and biodegradability. Starch is composed of a linear polymer (amylose) and a branched polymer (amylopectin) (Scheme 3). The degree of starch crystallinity is affected by the amylose content which depends on the starch source. However, native starch generally exists in a granular state due to its inherent hydrogen bonding between molecules, and this makes the dispersion of starch into a polymer matrix at a fine scale difficult. Thermoplastic starch (TPS) is obtained by mixing starch powder, water, and/or plasticizers, such as polyols, mono-, di-or oligosaccharides, fatty acids, lipids and derivatives, through a gelatinization' process. By definition, gelatinization is a transition process that occurs in the presences of water and heat, during which the intermolecular bonds between starch molecules break down, and the starch paste is obtained.

Blending of polymers is an effective alternative way to develop new materials with desired properties. The current study focuses on biodegradable PHB based blends with better thermal and mechanical properties. The objectives of the present study are:

- Improve the processability and impact resistance of PHB by adding plasticizers, fillers, such as modified starch (Polycarb);
- Improve the mechanical and thermal stability of PHB.

The improvement in thermal stability is attained by either lowering melting temperature or heightening the thermal decomposition temperature, i.e. avoid or retard the chain scission degradation.

2. Experimental Procedures

The materials used in the present study comprises Polycarb, PHB and biofuel glycerol, in blends made through a twin extruder and later on the testing samples were made using an injection moulding machine. The study aims to verify the possibility of reduce the cost of PHB and increase its availability, since the production capacity of the company is about 60 ton/yr. Since the melting temperatures for each component were different the processing was a significant issue to obtain blends with better mechanical properties when compared to its net polymers.

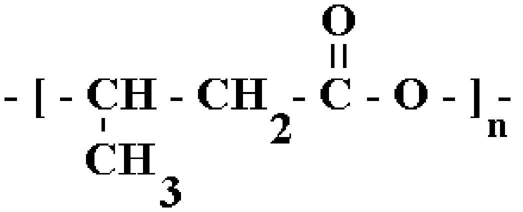
2.1 Material

The first raw material is the biofuel glycerol, a by-product from the biodiesel industry. It is a clear, colourless, viscous, sweet-tasting liquid belonging to the alcohol family of organic compounds; its molecular formula is $HOCH_2CHOHCH_2OH$. Also is known as glycerin, a term ordinarily applied to commercial materials containing more than 95 percent glycerol. The biofuel glycerol was obtained from the company Bioenergy Biopar Paraná, specializing in manufacturing and marketing of biodiesel. The plant is located in Rolândia in northern Paraná, Brazil. The company has daily production capacity of 120,000 litres of biofuel and about 43 million litres per year. It has made investments to expand production capacity; the volume will reach 100 million litres annually. Currently, Biopar has tanks for storage of 3.3 million litres. The main raw materials used in the production of biodiesel are vegetable oil - using soy, canola and wild radish - and animal fat. The Biopar markets its products in the auctions of the National Agency of Petroleum, Natural Gas and Biofuels (ANP). Besides the domestic market, the company plans to market the product also in the international market.

The other component is Polycarb, a polysaccharide derived biopolymer synthesized in-house at the Faculty of Forestry, University of Toronto.

Sain et al., 2008, US Patent US 2008/0308965 A1, developed the modification of starch by specific fungal isolates of the genus *Ophisotoma* (Sain et al., 2008). The complex process of modification of starch by using these fungal species has been attributed to the production of fungal exopolysaccharides which may be contributing to the increase of the molecular weight of the polymer and the mechanical properties, as well as in the reduction of the water adsorption and improvement of some mechanical properties. The Polycarb® is susceptible to higher temperature processing parameters compared with native starches from which these polymers are derived. The optimum processing conditions are at the range of 120°C.

The third component of this study is PHB. Poly-3-hydroxybutyrate (PHB) (trade name BIOCYCLE) was supplied by PHB Industrial S/A (Usina da Pedra-s/n Serrana, SP, Brazil) in powder form. The polymer had a weight-average molecular weight of 600,000 g/mol and melting point ~ 170°C. The formula for PHB is shown below, in Figure 1:



$$-[-\underset{CH_3}{CH}-CH_2-\overset{\overset{O}{\|}}{C}-O-]_n-$$

Figure1. PHB formula

The plastics due to its possibility of molding, processing and storage are appropriate for packaging applications around the world. Although, the traditional plastics are fossil based, not biodegradable and remain in the nature for centuries, being one important item in the landfills, littering streets and rivers and potentially harmful to the environment when incinerated. Therefore its replacement by the bioplastics for food packaging is an ecological way to reduce the environmental impacts of these materials, with gains for the society. Among these bioplastics, it can be listed the starch based, oxodegradables and the PHB, that degraded when exposed to the biological or physical active environment. In Brazil the PHB is produced from the sugar cane, a renewable resource, in which Brazil has the highest technology in the world. In this work the PHB was tested for application in food packaging (food trays) (Leao et al., 2009).

2.2 Methods

The composites were prepared in a twin-screw extruder, model ZSK-25, Coperion, L/D ratio of 25, at 180 rpm and the temperature profile of 150, 155, 160, 165 and 170 ºC. The programming of the temperatures always tried that the process temperature were less than 180 ºC. This equipment was used to compound the three components. The biofuel industry glycerol was mixed with Polycarb separately and then further mixed with PHB for the subsequent formation of pellets. The screw design used is showed in Figure 2. The feeding process was the one in which both components (Polycarb+ biofuel glycerol) and PHB are introduced on the same time to avoid overheat.

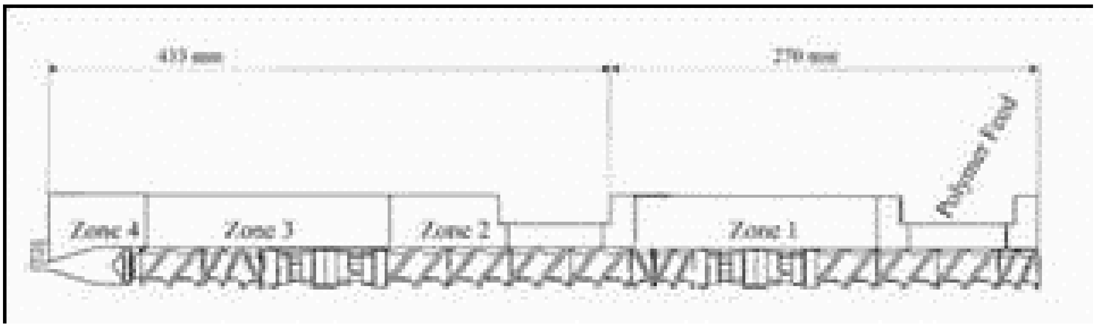


Figure 2. Screw profile used in the experiment

The material was compounded through extrusion process and later on the samples were prepared in a injection molding machine. The ratios used are described below at Table 1. One of the main objectives of the present study was the maximize the PHB, since the Brazilian production is low for the demand. Therefore the blends started at 70% of PHB content. The biofuel glycerol was tested in two levels, at 0% where only the other two components were present and at 46% based on the Polycarb weight.

Table1. Experimental design for the three components (% wt/wt)

PHB	**Polycarb**	**Biofuel Glycerol**
70	20	0
60	30	46
50	40	
40	50	
30	60	
20	70	

The extruded pellets were dried at 105°C for 4 hours to eliminate residual humidity from the fiber before the injection molding of the samples.

The samples were produced through injection molding process at 190°C, according to ASTM standards, in an automatic injection molding machine, Sandretto, 65 ton, model Micro. Prior to mechanical testing, the samples were conditioned at (40 ± 5)% relative humidity, (25 ± 2)°C for 40 hours. Notched Izod Impact tests were made using a Tinius Olsen pendulum type impact machine according to ASTM Standard D-256 with unnotched samples in ten specimens. At least ten specimens of every composite were tested to obtain the impact strength. Test were performed at UNESP laboratories using a Brazilian universal testing machine, brand EMIC DL 3000, following ASTM standards: tensile testing (ASTM D638); and flexural testing (ASTM D790). For flexural and tensile tests five specimens were used. The samples dimensions follow ASTM standards.

The produced samples are shown in Figure 2 (injection molded samples) and Figure 3 (thermoformed sheet), were can be observed the samples for testing and a prototype for a package tray, using a hot press for thermoforming.

Figure 2. Samples produced by injection molding technique ready for testing (ASTM standards)

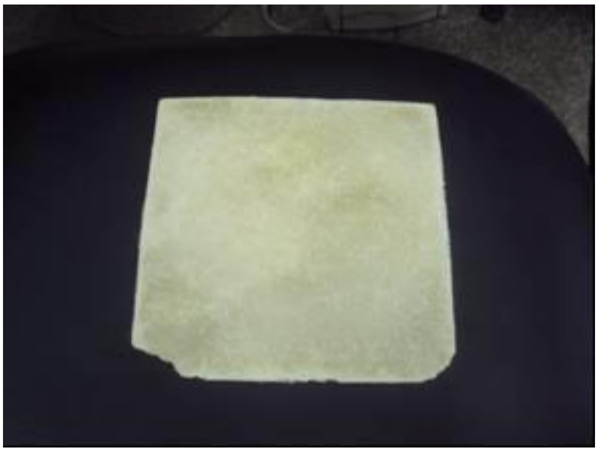


Figure 3. Thermoformed sheet produced using a blend of PHB/Polycarb/biofuel glycerol

2.3 Thermogravimetric analysis

Thermogravimetry analysis (TGA) was performed on a Shimadzu instrument (Japan). The temperature was ramped at a heating rate of 10 °C/min under nitrogen, to a temperature well above the degradation temperature of the polymers (500 °C).

2.4 Dynamic mechanical thermal analysis (DMTA)

Dynamic mechanical thermal analysis (DMTA) is a thermal analysis technique used to measure changes in the viscoelastic response of a material as a function of temperature, time, or deformation frequency.

DMTA measurements of PHB/starch blends were performed using DMA Q800 apparatus (TA Instruments Inc, USA) in the flexure (Dual Cantilever) mode (L0 = 35mm). Rectangular specimens (width ~ 13mm, thickness ~ 3mm, L0 = 35mm) of PHB/maize starch blends, PHB/PLA blends and PHB/PLA/HYLON VII blends were prepared. The specimens of PHB/maize starch blends were heated from -50 ºC to 100 ºC at 3 ºC /min, while the specimens of PHB/PLA blends were heated from -50 ºC to 150ºC at 3ºC/min, with a constant frequency of 10 Hz. The storage modulus (E`), loss modulus (E``) and loss factor (tan δ) were recorded.

3. Results and Discussion

It is important to mention that the blends are very processing sensitive and the extrusion conditions are key affecting the mechanical properties of the composites. The compound process was made using a kynetic mixer, brand MH, from Brazil (Guarulhos, SP) and directly into the extruder. Several trials were made using the same blend ratio and it was observed that the extruder process gave the best properties. A pre-mixing for Polycarb and biofuel glycerol was also important, reducing the visible particles of the starch in the compound. Later, the polycarb/biofuel glycerol mix was incorporated into the PHB. The results showed a better mixing when compared to a three way direct mixing. Neverthless a wide range of blends were tested from 30 to 70% of each main component (PHB and Polycarb), except in case of the blends showed no compatibility and no plastification.

The MFI was tested using the ASTM standards for PE (polyethylene), due to the narrow processing window of PHB and the heat damage suffered by the Polycarb at higher temperature. The MFI were low for most of the blends, but adequate for extrusion and some injection moulding applications, where fast cycles are not important (Table 2). For a better format in the tables the heading word Glycerol will be used.

Table 2. MFI of the main blends

Treatment	**MFI** **g/10min**
20% PHB/80% Polycarb	1.7
30% PHB/70% Polycarb	1.2
40% PHB/60% Polycarb	1.4
50% PHB/50% Polycarb	5.5
60% PHB/40% Polycarb	7.4
70% PHB/30% Polycarb	9.9
20% PHB/80% Polycarb/46% Glycerol	2.1
30% PBH/70% Polycarb/46% Glycerol	3.4
40% PHB/60% Polycarb/46% Glycerol	4.2
50% PHB/50% Polycarb/46% Glycerol	6.1
60% PHB/40% Polycarb/46% Glycerol	7.8
70% PHB/30% Polycarb/46% Glycerol	11.8

Another property studied was the hardness, measured by Shore D. In this case, this property is important if a food package tray suffer some action, such as an intruder (knife or fork). By the results showed in Table 3, can be observed that the PHB increased the surface hardness.

Table 3. Surface hardness measured by Shore D for the main blends

Treatment	**Shore D**
20% PHB/80% Polycarb	28
30% PHB/70% Polycarb	31
40% PHB/60% Polycarb	46
50% PHB/50% Polycarb	51
60% PHB/40% Polycarb	56
70% PHB/30% Polycarb	61
20% PHB/80% Polycarb/46% Glycerol	33
30% PHB/70% Polycarb/46% Glycerol	38
40% PHB/60% Polycarb/46% Glycerol	42
50% PHB/50% Polycarb/46% Glycerol	55
60% PHB/40% Polycarb/46% Glycerol	63
70% PHB/30% Polycarb/46% Glycerol	64

Table 4 shows the results for impact resistance for the studied blends, using the ASTM standard for IZOD testing. The impact resistance was obtained by the PHB component, although 50/50 was the best treatment. The addition of biofuel glycerol did not reflected in any improvement for the impact resistance property, and for some treatments were even negative. When compared to pure PHB, prior results reported by Leao et al., 2009 these blends showed lower value.

Table 4. Impact resistance (IZOD) for the main blends

Treatment	**J/m**
20% PHB/80% Polycarb	5.29
30% PHB/70% Polycarb	6.95
40% PHB/60% Polycarb	9.97
50% PHB/50% Polycarb	11.11
60% PHB/40% Polycarb	9.20
70% PHB/30% Polycarb	4.17
20% PHB/80% Polycarb/46% Glycerol	4.18
30% PHB/70% Polycarb/46% Glycerol	4.24
40% PHB/60% Polycarb/46% Glycerol	4.35
50% PHB/50% Polycarb/46% Glycerol	5.52
60% PHB/40% Polycarb/46% Glycerol	5.62
70% PHB/30% Polycarb/46% Glycerol	7.52

Table 5 shows the results for flexural resistance (MPa) for the studied blends. It can be observed that the addition of Polycarb at high levels did not improve this mechanical property. Nevertheless, the addition of Polycarb at low level, such as 30% was appropriate, with some improvement. The addition of biofuel glycerol in the blend did not reflected in significant improvement for this property.

Table 5. Flexural resistance at maximum force (MPa)

Treatment	**MPa**
20% PHB/80% Polycarb	11.13
30% PHB/70% Polycarb	10.87
40% PHB/60% Polycarb	14.37
50% PHB/50% Polycarb	22.03
60% PHB/40% Polycarb	23.87
70% PHB/30% Polycarb	33.79
20% PHB/80% Polycarb/46% Glycerol	16.57
30% PHB/70% Polycarb/46% Glycerol	20.32
40% PHB/60% Polycarb/46% Glycerol	15.11
50% PHB/50% Polycarb/46% Glycerol	24.30
60% PHB/40% Polycarb/46% Glycerol	28.45
70% PHB/30% Polycarb/46% Glycerol	31.28

Table 6 shows the tension resistance for the studied blends. The addition of Polycarb and biofuel glycerol also did not improve the blends performance in most of the treatments. Although, the blends can take a significant amount of these two components aiming the price reduction and supplement the PHB production capacity.

Table 6. Tension resistance at maximum force (MPa)

Treatment	**MPa**
30% PHB/70% Polycarb	9.11
40% PHB/60% Polycarb	10.49
50% PHB/50% Polycarb	9.22
60% PHB/40% Polycarb	15.90
70% PHB/30% Polycarb	17.24
20% PHB/80% Polycarb/46% Glycerol	9.33
30% PHB/70% Polycarb/46% Glycerol	8.90
40% PHB/60% Polycarb/46% Glycerol	6.03
50% PHB/50% Polycarb/46% Glycerol	16.83
60% PHB/40% Polycarb/46% Glycerol	12.86
70% PHB/30% Polycarb/46% Glycerol	14.93

Thermogravimetric analysis

Figure 4 shows the TGA thermograms of PHB biofilm and its blend. The thermal degradation of extracted PHB proceeds by a one-step process with a maximum decomposition temperature at 291 ºC. This thermal degradation at maximum decomposition temperature of approximately 300 ºC is mainly associated with the ester cleavage of PHB component by β-elimination reaction (Choi et al., 2003). However, the thermal decomposition patterns of PHB/Polycarb followed a considerably different pattern from the single-step reaction of the PHB. Maximum decomposition temperature also increased from 291 ºC to 500 ºC. The temperature of 291°C was found to be the maximum decomposition temperature for biofilm made with PHB. The decomposition temperature for the PHB/Polycarb made in this experiment was beyond 300 °C. The residual weight of different blends at temperature beyond 300 °C is shown in Table 7.

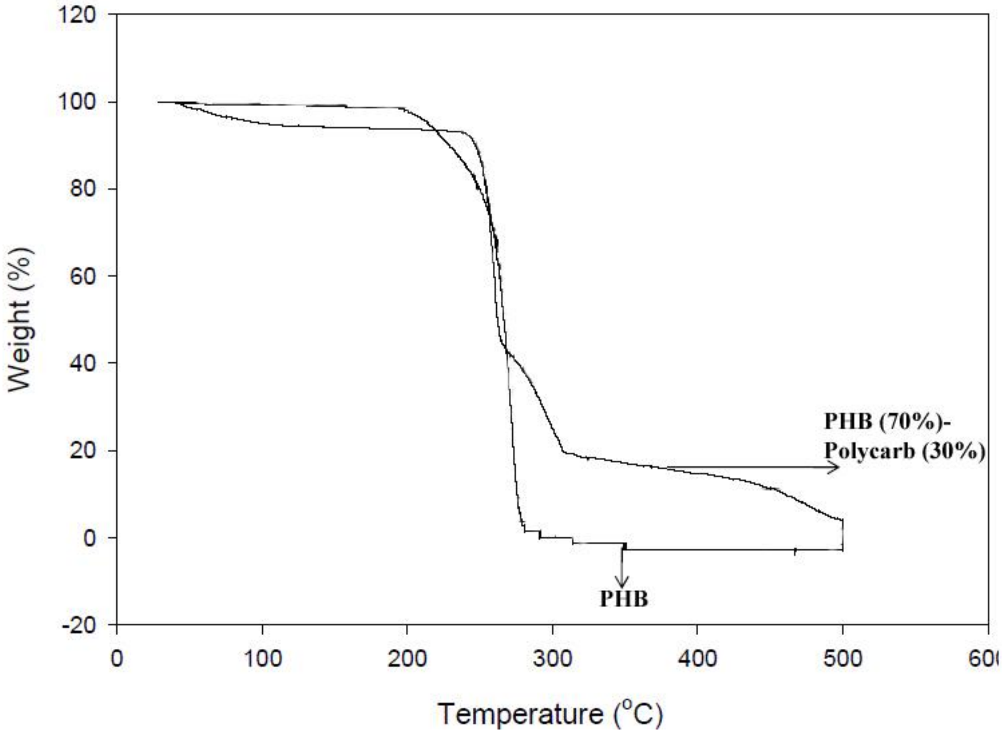


Figure 4: TGA curves of extracted PHB and PHB/Polycarb blends.

Table 7: Initial and maximum decomposition temperatures evaluated from TGA.

Biofilm	**T_i (°C)***	**T_{max} (°C)**	**Residual weight (%) at 300 °C**
PHB (Sigma)	234	302	0
PHB (70%)-Polycarb (30%)	98	358	24.9

*Values determined at a 5 % weight loss on the TGA thermograms.

Dynamic mechanical thermal analysis (DMTA)

Figure 5 to Figure 7 show the DMTA curves for PHB/Polycarb blends with Polycarb content up to 30 wt%. In the current study, the DMTA data for pure PHB were not obtained due to its poor formability. As shown in Figure 5, PHB/Polycarb blends exhibit typical dynamic mechanical properties for semicrystalline polymers. The storage modulus decreases from about 0°C due to the glass transition relaxation of PHB.

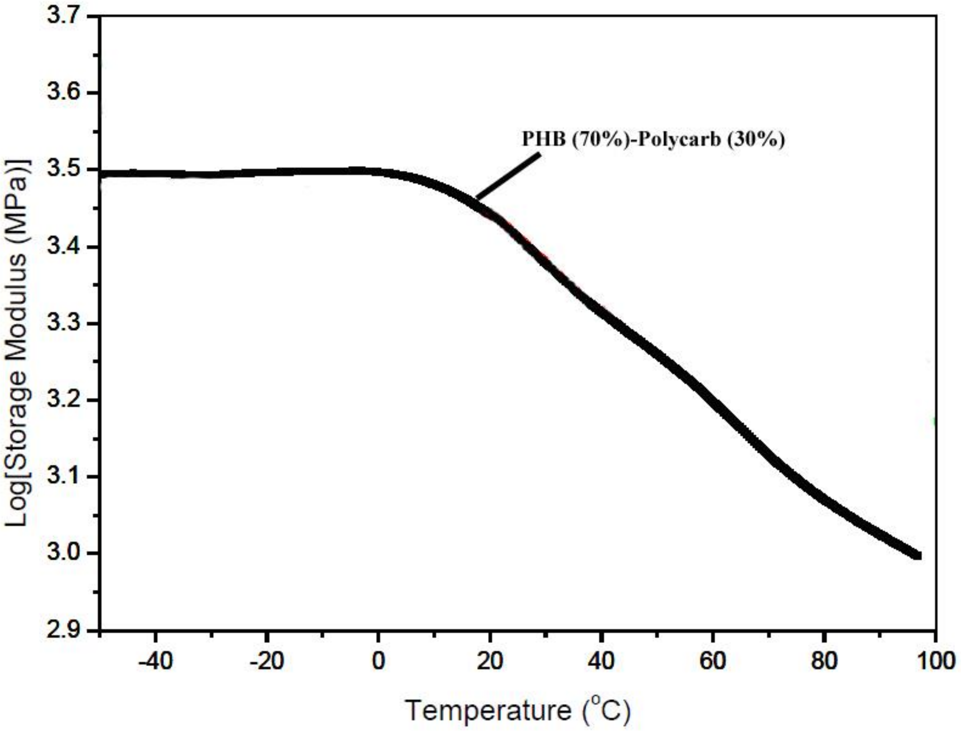


Figure 5 Plot of log (storage modulus (E‘)) vs. scan temperature for the PHB/Polycarb blends

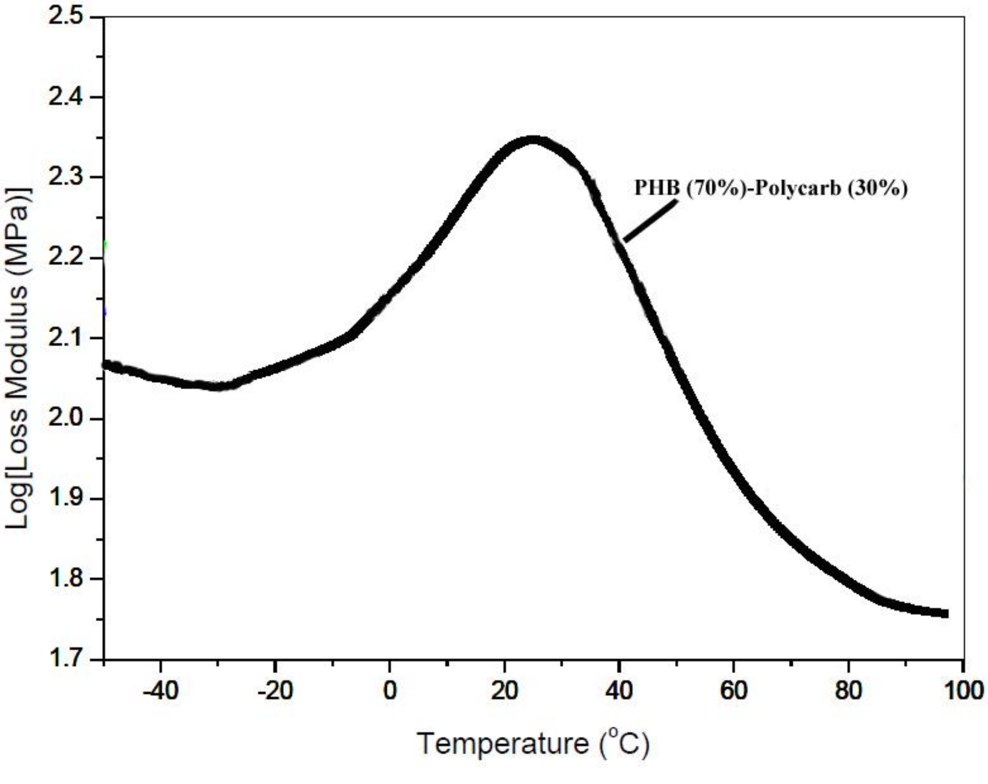


Figure 6 Plot of log (loss modulus (E‘‘)) vs. scan temperature for the PHB/Polycarb blends

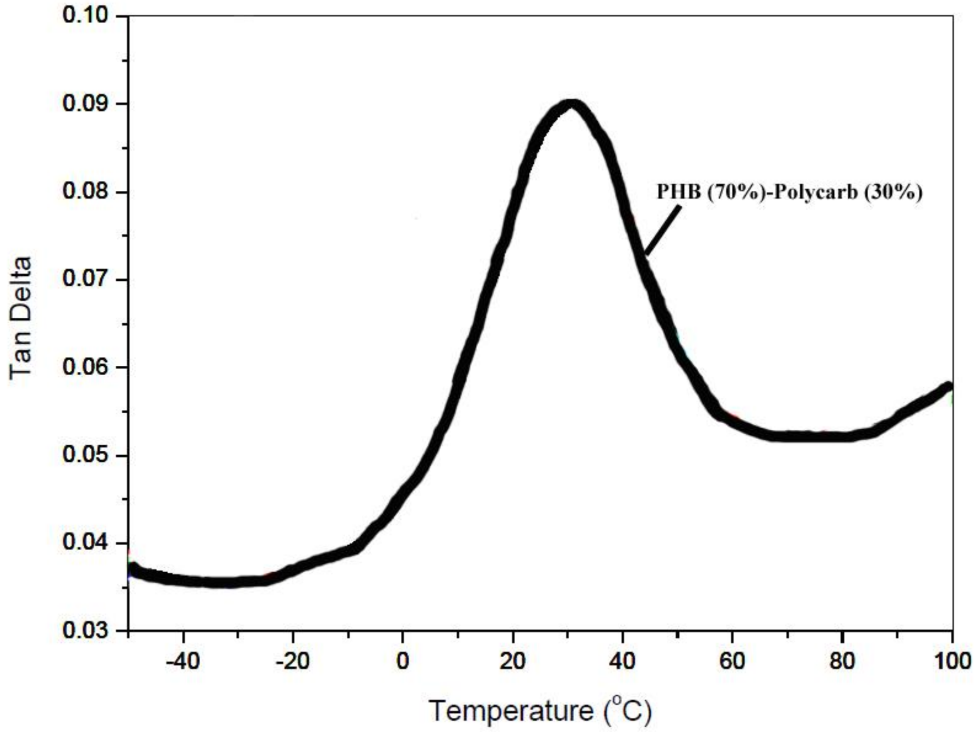


Figure 7 Plot of tanδ vs. scan temperature for the PHB/ECO-MAIZE blends

The peaks present in the E´´ and tanδ curves in the range between 0 and 60°C is attributed to the glass transition (Figure 6 and Figure 7). The glass transition temperature values obtained from Figure 5 was observed to be 32 °C. The sharp Tg is associated with the small amount of Polycarb acting as a filler to reduce the chain mobility of PHB and is possibly due to the interaction between PHB and Polycarb hindering the hydrogen bonding between adjacent chains of PHB.

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C.3. ETHANOL AS SOLVENT FOR VEGETABLE OIL EXTRACTION AND MEAL DETOXIFICATION

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Abstract

Ethanol in Brazil is produced from sugarcane, is biodegradable and less toxic than hexane, presenting economic advantages as an alternative solvent in the extraction also by generating a vegetable oil with reduced free fatty acids and phospholipids contents, i.e. a lower cost feedstock for biodiesel production. The oil extraction using ethanol as the solvent generates two miscellae (oil+solvent), one rich-in-oil (rich miscella) and another rich-in-ethanol (poor miscella). Rich-in-oil miscella can be converted directly into esters (biodiesel) without refining using ethanol and chemical or enzymatic catalysts. The poor miscella can be recirculated as the solvent in the process without the need for distillation processes. The meal from this process is high in protein, free of antinutritional and toxic substances without further treatment. Energy feasibility of the productive chain of soybean biodiesel using ethanol as solvent and acyl acceptor was proven demonstrating that the replacement of hexane and methanol (from non-renewable sources) by ethanol (a renewable source) is promising and is of great importance for the positive impacts to the environment (less waste production, safer handling and storage) and to the lower cost (reduction of steps in the processing of extraction).

1. Introduction

Even before the 1960s environmental concern regarding world energy sources depletion and global warming was an important issue (Boustead and Hancock, 1979). The high energy demanded in the industrial and domestic sectors, added to the pollution problems caused by the use of fossil fuels has increased the interest and need to seek for energy from renewable sources with lower environmental impact. Similarly to the energy sector, there has been great interest in other sectors for replacing process components from non-renewable by renewable sources such as alternative solvents substitutes for hexane in the oil extraction process. The vegetable oil can be extracted by pressing, solvent or a combination of both (Mc Clements and Decker, 2010). The pressing process is most recommended for oilseeds with oil content larger than 20%, and solvent extraction is a more efficient alternative to pressing to extract the oil from not so rich-in-oil seeds (Johnson, 2002). The extraction is usually performed with petroleum solvents such as hexane, solubilizing the intracellular oil, without reacting with other components from the matrix (Johnson, 2002). However, hexane has some disadvantages, such as inflammability, explosibility, toxicity besides being a fossil solvent. Prolonged exposure to hexane affects the central nervous system, causing drowsiness and dizziness and it can be fatal if swallowed or in contact with the mucosa (Sigma-Aldrich, 2015). Solvents as n-heptane, n-propanol, isopropyl alcohol, terpenes and ethanol can be used as substitutes in the oil extraction with similar yields to those achieved by hexane (Gandhi et al. 2003, Li et al., 2014). Actually, ethanol was used as solvent in the oil extraction for the first time in an industrial plant, in 1934 in Manchuria, North Asia. Since then the topic has been of interest and the technical and energetic feasibility of this use has been studied (Beckel et al., 1948). In Brazil, since the 1980s research has proved the extraction of oil with ethanol instead of hexane and as the acyl acceptor in biodiesel production instead of methanol (Regitano-d'Arce et al., 1987; Regitano-d'Arce et al., 1994a; Sangaletti et al., 2013; Sangaletti-Gerhard et al., 2014a). Ethanol as the extraction solvent promotes a pre-refining, with partial removal of phospholipids and free fatty acid from soybean oils (Sangaletti-Gerhard et al., 2014a). Furthermore the process proves to be very promising on the energy supply chain soybean biodiesel since it generates high-quality products, less waste and high value byproducts (Sangaletti-Gerhard et al., 2014b).

2. Oil extraction with ethanol and its products

Several solvents may be used in the extraction process and the choice depends on the desired final product (oil or meal). In oil extraction with hexane, miscella is usually distilled for separation from the crude oil that is sent for refining and the solvent that, once recovered by evaporation and condensation, is reused in subsequent extractions (Johnson, 2002). The meal obtained in this process should be free from the solvent (solvent recovery) and toasted (soybean) to eliminate anti-nutritional compounds in order to be used as food or feed. However, toasting step is a high energy consuming step in the extraction plant due to the high temperatures needed to inactivate the urease, as well as other undesirable compounds in soybean (for example) (Sheehan et al., 1998). Unlike hexane, the use of ethanol as the solvent for soybean oil extraction eliminates the solvent distillation and the miscella (solvent + oil) refining steps, by cooling it to less than 30°C, resulting in three phases: a rich and a poor miscella, and gums. The poor miscella containing 91% ethanol when used as solvent for 3 cycles of extraction followed by a final 99% ethanol cycle can reach 83% oil removal efficiency. The rich miscella (90% oil and 7.8% ethanol) is suitable for biodiesel production without the need for desolventization and any refining steps. Otherwise, it can be refined and used for food. The rich miscella has very similar characteristics to the degummed oil, a great economic advantage over crude soybean oil extracted with hexane, which requires at least degumming and alkali refining for biodiesel production. Furthermore, the soybean rich miscella oxidative stability is guaranteed by the antioxidants extracted. Rich miscella is three times more stable than degummed oil (Table 1). Compounds like tocopherols, phospholipids and phenols may be extracted to the miscella during this process due to the more polar character of ethanol (Koprivnjak et al., 2008).

Table 1. Rich in oil miscella and degummed soybean oil chemical composition

Parameter	Ethanol extraction [a]	Hexane extraction[b]
Total lipids (w/w %)	90.0 ± 1.0	98.0
Alcohol (w/w %)	7.6 ± 0.1	-
Non-volatile matter (w/w %)	91.7 ± 0.4	-
Phospholipids (w/w %)	0.6± 0.0	0.02
Unsaponifiable matter (w/w %)	1.0 ± 0.2	1.5
Peroxide value (meq/kg miscella)	10.9 ± 0.2	10.0
Acid value (% oleic acid)	0.4 ± 0.1	0.7
Water (w/w %)	0.3 ± 0.2	-
Oxidative stability at 110°C (h)	22.0 ± 2.0	8.0[c]

[a]: Sangaletti-Gerhard et al. (2014a)

[b]: Sheehan et al. (1999)

[c]: Preliminary results

The higher quality of the resulting meal compared to the one from the hexane process is found in the higher protein content (48%), lighter color and lower toxicity (safe levels of protease inhibitors, lectins, phytates, saponins and oligosaccharides) (Sangaletti-Gerhard et al., 2014a). In addition, ethanol removes other undesirable compounds such as the chlorogenic acid in sunflower seeds, gossypol in cottonseed and aflatoxin in peanuts (Fonseca and Regitano-d´Arce, 1993, Regitano d'Arce et al., 1994b; Hron et al., 1994) adding more value to the meal.

3. Viability of the rich miscella in the biodiesel production chain

Biodiesel is a fuel comprised of esters of fatty acids mainly obtained by transesterification reaction, between vegetable oil or animal fat (triglyceride) and a short chain alcohol (methanol or ethanol) in the presence of a catalyst (Balat, 2007). The main economic factor in the biodiesel production is the feedstock cost (oils or fats and alcohol), processing and logistics. The lipid feedstock represents up to 75% of the product cost, requiring a simple and efficient oil extraction from the matrix, with the elimination of processing steps and low waste generation; assuring high yields of biodiesel (Ma and Hanna, 1999; Haas and Foglia, 2006). Direct transesterification with ethanol as the acyl acceptor catalyzed by enzyme or by an alkaline catalyst was possible due to the low water, free fatty acids and phospholipids contents of the unrefined rich miscella with high conversion of fatty acids ethyl esters (FAEE). The biodiesel production using 9.5 % commercial Novozym®435 lipase yielded 94% FAEE (molar ratio 1:4, rich miscella: ethanol) using 5% tert-butanol as cosolvent at a temperature of 40 ° C for 24 hours (Sangaletti et al., 2013). The transesterification reaction with alkaline catalyst (0.6% NaOH, molar ratio 1:12 rich miscella: ethanol) for 60 min at 30 °C reached 97.2% FAEE, with more energetically advantages compared to the conventional industrial process (Sangaletti-Gerhard et al. 2014a, Sangaletti-Gerhard et al., 2014b). In addition to the high performance, biodiesel produced from rich miscella presented all parameters within the limits set by the National Petroleum, Natural Gas and Biodiesel (ANP), which allows its commercialization in Brazil.

The energy viability of biodiesel production chain using the rich miscella rich, ethanol and alkaline catalyst, was determined and compared to the conventional biodiesel production in which hexane is the oil extraction solvent and methanol, the acyl acceptor to produce biodiesel. Figure 1 illustrates the similarity in the amount of energy demanded between the field (crop) step (around 20 MJ) and the soybean flaking step during preparation for extraction (around 14 MJ) in both cases. As the extraction step using ethanol required three times more energy than the conventional process, a reduction of 60% for the ethanol process would already make it competitive. However, this energy consumption is balanced in the biodiesel production step using the rich miscella, which demanded four times less energy (2.3 MJ) compared to the conventional transesterification process (9.5 MJ). More details on the energy viability between the conventional process of biodiesel and processes using the rich miscella can be found in Sangaletti-Gerhard et al. (2014b).

The energy return on investment (EROI), which is determined by the amount of energy output (OP) divided by the energy invested (IP) by the economic system, was of 2.0 and 1.64 for conventional and alternative process, respectively, which means that the system produces more energy than it consumes. Obviously, the energy balance (∑output energy - input energy) is positive for both processes, conventional (55.4 MJ) and the alternative (44.3 MJ), assuring the great potential for the ethanol process. On the top of this, the process using ethanol as the solvent saves 1.7 MJ energy from each refining step after the conventional extraction (degumming and alkali refining) and produces less waste (gum and soapstock), as the gums are not always directed to lecithin production.

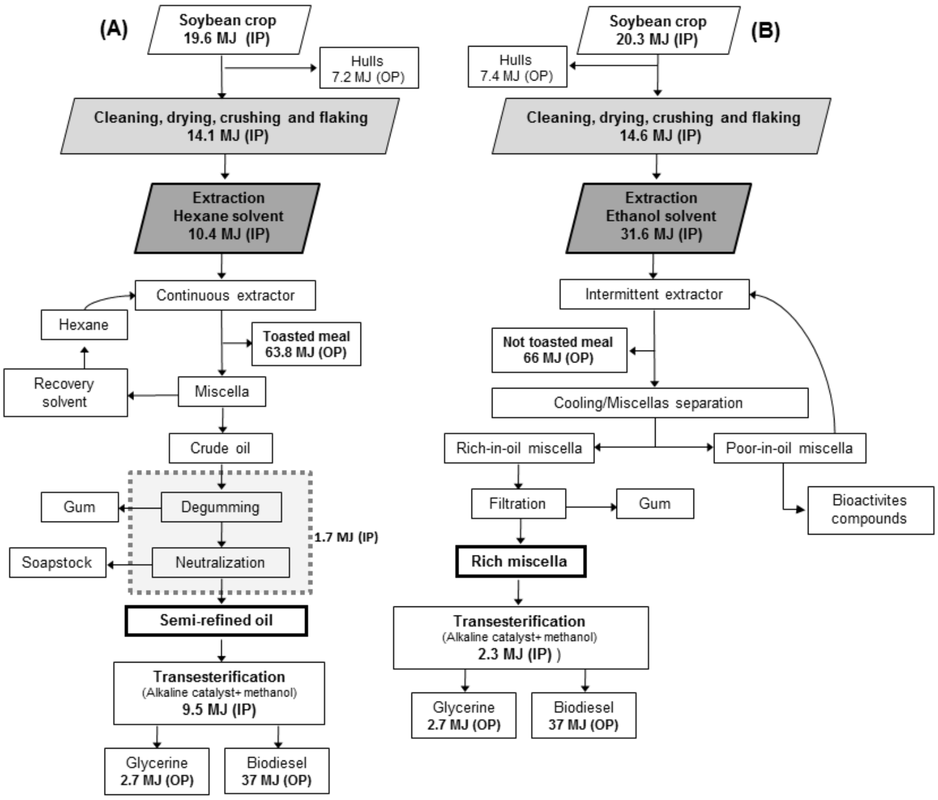

Figure 1. Biodiesel productive chain: Conventional process (A) and Alternative process using Ethanol (B).

IP: input, OP: output. (Sangaletti-Gerhard et al., 2014b)

In conclusion, replacing hexane as the oil extraction solvent and methanol as the acyl acceptor for ester production is a promising alternative in the vegetable oil/biodiesel productive chain due to the less energy use and cleaner process. Ethanol as the solvent adds value to the products and byproducts as several known steps in the oil extraction process are not necessary such as meal detoxification as well degumming and alkali refining.

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C.4. PERSPECTIVES OF SUSTAINABLE FOOD PROCESSING WITHIN A BIO-ECONOMY

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Abstract

The concept of the bioeconomy covers the agricultural economy and all manufacturing sectors and associated service areas that develop, produce, process, handle or utilize any form of biological resources, such as plants, animals and microorganisms. There are five priority fields of action for further development: global food security, sustainable agricultural production, healthy and safe foods, the industrial application of renewable resources and the development of biomass-based energy carriers[1].

Sustainable food processing as key driver of the bioeconomy covers process-product- operation interactions, where selected examples of innovative thermal, electro-magnetic, mechanical and combined processes will be presented and are introduced hereafter.

Modular thermal micro process engineering was effectively applied to improve upscaling of microbial inactivation processes, but its mechanical process elements could also be used for tailored structure formation and synthesis. Electro-magnetic based pulsed electrical field PEF processing enables an efficient use of biomass and energy within different value chains. Consequently, PEF was successfully implemented into the potato and fruit juice processing chains with a maximum capacity for cell disintegration up to 80 tons per hour. During mechanical high pressure processing in batch, focused investigations on the property changes within pure water and more complex systems, such as proteins and microorganisms, enabled a detailed understanding of the respective process-product- operation interactions. Special focus was laid on bacterial spores, the target of sterilisation. After studying spore inactivation in very detail, classical high pressure preservation could be optimized through combined thermal and mechanical processes such as high pressure thermal sterilisation as well as continuous ultra-high pressure processing up to 400 MPa as innovative multi hurdle technologies for gentle sterilisation of healthy and high quality food. Advanced approaches relying on innovative raw materials and biorefinery concepts to create new and innovative value chains could even increase the impact of sustainable food processing. Such innovative value chains could be linked to novel opportunities to value alternative protein sources. By using novel proteins from algae, food security and sustainability of the protein supplies can be significantly improved. Connected biorefinery approaches within these innovative value chains realise the sustainable material and energetic utilisation for a valorisation of all side streams by applying combined processes.

Holistic life cycle sustainability assessment, aligned with the introduced process innovations, can evaluate the suggested solutions on a multi parameter base, in terms of improved food

production sustainability. A focused knowledge transfer via food processing workshops as well as student and expert exchanges will assure the mid and long term impact of the presented solutions.

Keywords: bioeconomy, sustainable food processing, sterilisation, biorefinery, life cycle sustainability assessment

Reference

[1] Bioeconomy Council Report, 2010, Berlin, Germany.

SESSION D: SOCIAL ASPECTS

D.1. CONSUMERS' RISK PERCEPTION OF GENETICALLY MODIFIED (GM) FOOD VS. NON-FOOD PRODUCTS: EMPIRICAL EVIDENCE FROM GERMANY

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Keywords: Risk perception, bioenergy, food, biotechnology, consumers, risk responsibility, trust

Abstract

Genetic engineering plays an important role for many products in bioeconomy such as food, pharma, feed, fiber and energy production (Diamond, 2009). However, there is a lack of research on differences in risk perception between different products including gene technology. This paper aims to assess consumers‘ risk perception and how consumers allocate risk responsibility between all actors of the supply chain for products from both genetically modified (GM) food and non-food crops.

In research on consumers’ perception of genetically modified organisms (GMO’s) ample literature exists on consumer acceptance and less on risk perception. However, various studies suggest that research on GMO risk perception is more powerful at explaining consumer behavior than research on acceptance (Mitchell, 1999; Grunert et al., 2001; Frewer et al., 2011; Hess et al., 2013). Therefore the following study focuses on consumers’ risk perception. Risk perception of GM food products is generally quite high in Europe (e.g. Grunert et al., 2001). But with the exception of pharmaceuticals there does not exist any research on consumers’ risk perception of other widely used biotech products. However, research in the areas of Psychology and Marketing suggests that consumers rate hazards differently between products. By comparing listings of several products Young et al. (1992) showed that risk ratings significantly vary across products. Dowling & Stealin (1994) emphasized that the consumers’ risk perception not only depends on the individual’s personal perception, but also on product-specific risk characteristics. While consumers’ risk perception of GM food has been widely analyzed there is a lack of research on comparing differences in risk perception with respect to product category. Against the backdrop of an emerging bioeconomy (that includes various products) it is of major importance to assess whether there exist differences in risk perception between products and what the underlying potential reasons are. In addition, risk responsibility analysis will investigate how consumers understand their personal role in the supply chain and how they perceive responsibilities to be allocated across the other actors in food and non-food supply chains for products including biotechnology. The implications of this analysis will allow to better understand consumer behavior and thus contribute to enhance the national bioeconomic policy strategy.

This study aims to analyze the relationship between risk perception and risk responsibility from the consumer's perspective employing a consumer behavior approach with stated preferences. Moreover the effects of perceived self-control and social trust will be elicited. In an economic setting of two different policy scenarios 440 consumers from Germany have been asked in a computer-based survey to state their risk perception for two products including GMO's.

A GM potato represents the food product whereas GM maize which is used for bioenergy production stands for the non-food product. Both the rising global demand for energy and the steadily increasing importance of biomass for energy production gives reason to focus on a non-food product that is used for biofuel and bioenergy production. In the policy scenario "Research & Development" (R&D) GM crops are only allowed to be cultivated for R&D purposes and in the "Full Commercialization" (FC) scenario it is allowed to fully market GM crops and products involving biotechnology. The setting thus leads to 4 groups of respondents (2 products x 2 scenarios).

The concept of risk perception builds on previous literature and is measured by three questions. Similarly to Moon & Balasubramanian (2003), the consumer was asked in a first step to rate the given risk statement on a 5-point Likert scale (e.g. "Do you agree on the following risk statement?"). Then she was asked to assess the perceived likelihood of the previous statement on a 6-point scale (e.g. "How likely do you think the risk is?"). Finally, she was supposed to rate the severeness of the event on a 5-point scale (e.g. "How severe do you think the risk is?"). The latter two variables have previously been validated as a measure for risk perception (Mitchell, 1999 based on Kogan & Wallach, 1964). All these questions relate to risks separated in four risk dimensions. Health and environmental aspects have been investigated to account for the most relevant risks according to literature on GMO risk perception. In addition, two aspects have been included that seem to be less relevant but are still of importance in the given context, namely socio-economic and ethical aspects. The consumers' attitude towards these risk dimensions has been measured by 41 corresponding attitudinal questions to account for individual differences.

According to Leikas et al. (2009) perceived personal controllability of the risk predicts judgements of risk responsibility. The higher perceived self-control is, the higher personal risk responsibility will be. This means, that judgements for other actors in the supply chain will be lower. However, literature has not included a simultaneous analysis of all supply chain actors, yet. Therefore reduced food and bioenergy supply chains have been used to paint the big picture of consumer's risk responsibility judgements accounting for most supply chain actors and product differences at the same time (see figure 1).

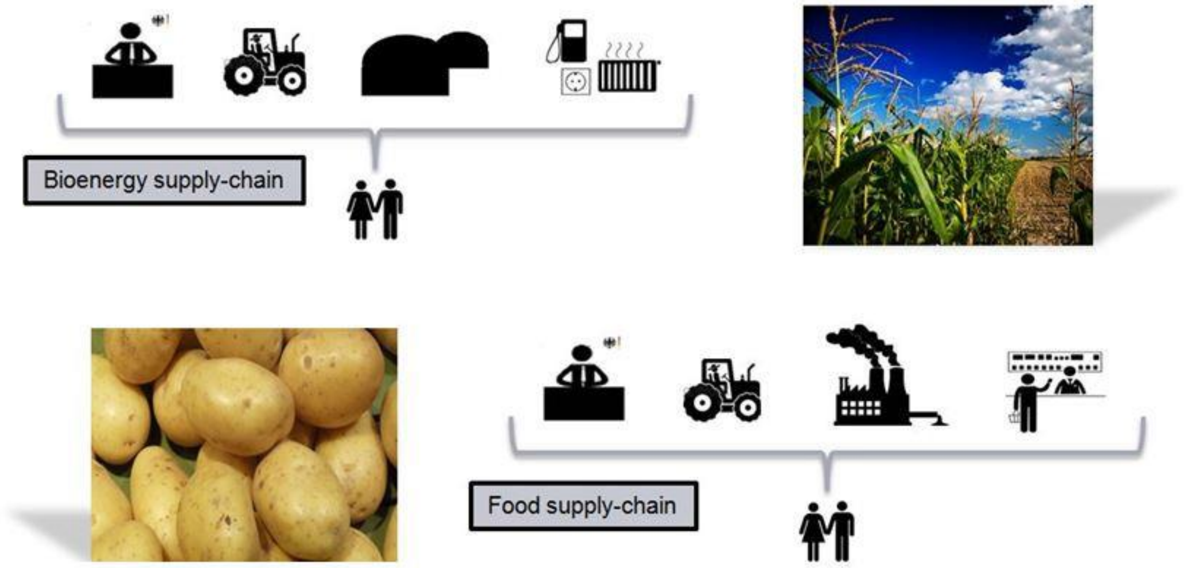

Figure 1: Schematic representation of reduced supply chains for the non-food product bioenergy (government, farmers, bioenergy producers and energy companies) and food (government, farmers, food processing industry and retailers) providing consumers with bioenergy and food produced from GMO's.

The concept of social trust plays an important role in consumer research on GM food (Siegrist, 2000) and is closely connected to risk responsibility judgements and risk perception. The higher the consumers' trust in authorities (who are responsible for applying genetic engineering or handling the modified products) the lower the risk perception is which in turn affects responsibility judgements. The integration of social trust allows for a more detailed picture of the relationship between risk perception and responsibility judgements and for a better understanding of the concept's role, particularly for a non-food GM product.

Partial least squares structural equation modeling techniques are used to analyze the gathered data. This approach combines canonical factor analysis and multivariate regression to establish statistical causal relationships between the variables.

Expected findings can be summarized to following hypotheses:

Based on findings in prior literature, the first hypothesis suggests product related differences in consumers' risk perception. From a recently conducted consumer focus group discussion we identified differences in consumers' risk perception between food and non-food products including GMO's. Thus:

H1: Risk perception is lower for bioenergy than for food.

Secondly, literature delivered clear evidence for a positive relationship going from risk perception and self-control to risk responsibility leading to

H2: Perceived risk and self-control positively predict personal responsibility.

Whereas the effect direction of self-control is clear, the effect size is not and hence it is not obvious how consumers perceive risk responsibility among the supply chain for different products. Consumers might feel a higher self-controllability for food than for bioenergy because they have a direct contact to the raw material and end-product. This would suggest that the personal risk responsibility judgement is higher for food. On the other hand, the severeness of a hazard immediately and negatively affects personal responsibility judgements. The more severe the perceived risk outcome is, the more responsibility consumers assign to other actors in the supply chain (Baron & Hershey, 1988). As consequences of risk associated with food might be perceived as more severe, because they might potentially affect the own health status, personal responsibility judgement could also turn out to be lower for food compared to bioenergy. Moreover, results of the above mentioned focus group discussion suggest that risks of bioenergy, that is made from GM crops, are not perceived as severe as risks associated GM food. Therefore the analysis should clarify which of the alternative hypotheses below is true.

H2: Risk responsibility judgements depend on product end-use:

*H2.0: Personal responsibility is higher for **food** risks versus*

*H2.1: Personal responsibility is higher for **bioenergy** risks.*

The following hypothesis relates to policy effects on risk perception and results are expected to be correlated with trust and self-control.

H4: Perceived risks in bioenergy production are higher in full commercialization scenario.

In order to be able to use the concept of social trust to explain model outcomes, the concept needs to be validated within the dataset. Accordingly, the last hypothesis aims to confirm previous findings and suggests that

H5: Social trust negatively predicts risk perception.

The above hypotheses have been illustrated together with the model in figure 2.

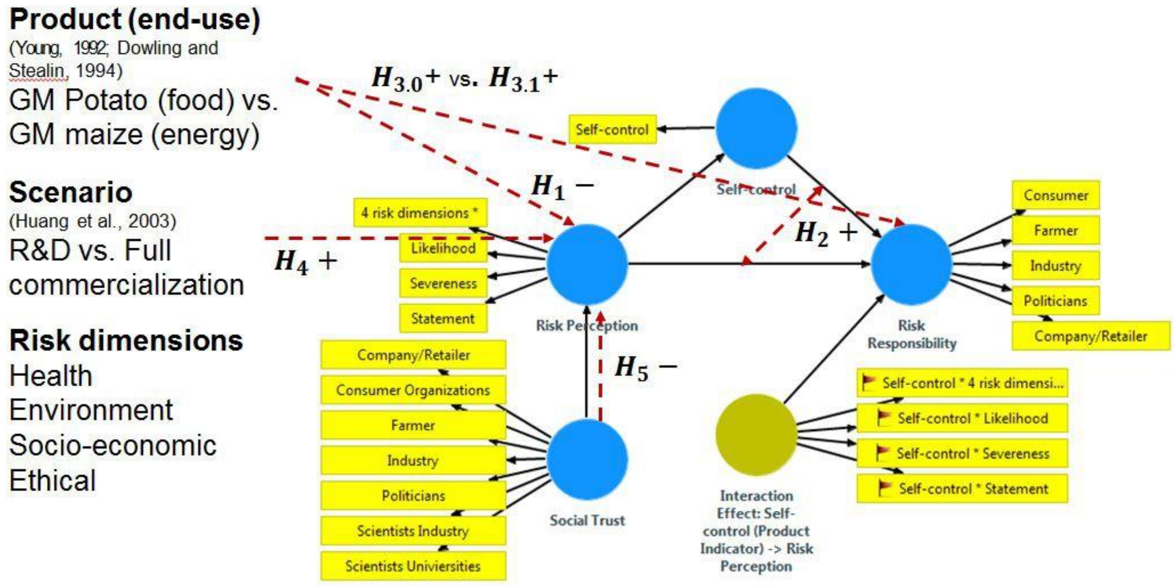

Figure 2: Structural Equation Model of the study. Blue circles represent model variables connected through black arrows indicating a causal relationship. The corresponding hypotheses are highlighted with red dotted arrows and the expected direction of relationship is indicated by "+" for a positive and "-" for a negative relationship.

Implications include insights into consumers' risk perception and decision making process. Differences in risk perception between product end-use (food vs. non-food), policy scenarios and risk dimension are of particular interest for the bioeconomic policy strategy and marketing. Responsibility judgement analysis will deliver insights into consumer behavior and help developing public health policy strategies.

This study provides unique insights into differences in consumers' perception of food vs. non- food products including GMO's. It will add to the current body of literature by providing a first product comparison study on consumers' risk perception. Moreover, it investigates interrelationships between existing risk concepts within an economic policy framework and provides a first simultaneous risk responsibility analysis across the food and bioenergy supply chains from the consumers' perspective.

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SESSION E: EDUCATION

E.1. ROLE OF EDUCATION TOWARDS A KNOWLEDGE DRIVEN DEVELOPMENT

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Significant changes occurring at multiple levels (economy, society, technology, environment) are challenging well established practices within the food system. Along innovation, sustainability is becoming a key driving force of modern food production chain, while quality and safety remain paramount objectives in continuous search to answer to consumer needs and expectations. Food security, energy and water shortage, shifting global population demographics, environment pollutants, nutritional and climate changes are nowadays the vital topics driving research and development in the agro-food sector.

New knowledge and know-how generated by fundamental research in food science as well as other peripheral scientific domains should be transformed into innovation and practices to facilitate their comprehensive utilization and implementation (Pittia et al., 2014) towards the benefit of the whole food sector and society.

To date the critical driving force and the cardinal role of education and training as the specific knowledge and skills determinant to lead innovation, promote and sustain economic development in all manufacturing sectors are broadly accepted. Consequently, EU and many other countries are promoting the implementation different actions and strategic programmes focusing on a 'smart, sustainable, inclusive growth' of the society by increasing the number of young people that successfully complete a Higher Education (HE) study, increasing investments in R&D, and innovation for achieving an improved knowledge base in the population.

Higher Education (HE) courses and degrees programmes based on an integrated knowledge to respond to the highly specific skills and competences required by the food manufacturing sector have been implemented in numerous universities. The uniqueness of Food Science and Technology consist on the capacity to merge a multidisciplinary approach with highly specialized sciences. These qualities are necessary when the aim is to achieve food products safe healthy and up to consumers' expectations (Costa et al., 2014).

Nowadays, Food Science and Technology/Engineering degree programmes are integral part of numerous educational schemes diversified based on learning outcomes and branches (e.g. Food science vs Food engineering), sectors of specialization (technology, engineering, nutrition, safety, quality, food production chain) and degree titles. However, graduates coming out from these curricula successfully get into the market system and occupy rather diverse positions within the public and private sectors.

In this framework, HE and training are playing a main role in providing the desired skills and the knowledge relevant for the job market and the professional career of the food scientist and technologists. While the interdisciplinary sector-specific skills are the fundamental of food scientists and technologists, the need to improve the so called personal or “soft” skills has been recently arisen from the job market (Maior et al., 2015; Flynn et al., 2012).

The education of the next 2.0 young generation equipped with 21st century know-how and skills, while simultaneously creating a knowledgeable workforce in the food sector implies the involvement of several actors with different backgrounds, expectations and responsibilities. Academia’s role in providing mastery sector specific knowledge along with learning related skills by reaching, however, a matured level, is not sufficient anymore. To provide the future generation of food scientists and technologist with required knowledge, skills and competences as well as the proper innovation and entrepreneur mind-set to meet the job market expectations, a paradigm shift is need in academia educational methodologies and learning outcomes.

The ISEKI_Food network has promoted since 1998 continuous and diligent projects (e.g. the FP7 Track_Fast, the Erasmus TN ISEKI_Food series) aimed on enhancing HE In the Food Science and Technology/Engineering sector. The ISEKI_Food projects were actually designed as a network of Universities and Research Institutions, Industrial partners as well as Professional and Students Associations of the food sector to foster collaboration, to develop mutual knowledge and exchange of ideas, at an EU and International level.

The last networking project (ISEKI_Food-4, www.iseki-food4.eu), has focused on modernization and upgrading food studies programmes, promoting employability and entrepreneurship of the graduated FS&T, and expanding lecturing qualifications of university teaching staff. Successful modernization of the HE food studies and enabling sustainable societal and economic growth require development of adequate academia-research-job market interactions and their improvement in a wider societal framework, and also the involvement of policymakers and other stakeholders to promote flow of knowledge and innovation.

Within this framework, worth of mention is the Erasmus+ KA2 “European FooD-Studies and Training Alliance” project (EuFoodSta, www.food-sta.eu/) aimed to establish an independent “EuFooD-STA Centre” made of virtual platform plus physical hubs to set international and sustainable collaborations between industry and academia in the food sector.

To ensure the sustainability of the network activities the ISEKI-Food Association (IFA, www.iseki-food.net) was founded in 2005 as non-profit, international organization to sustain the main initiatives of the ISEKI_Food network at EU and international level aimed to favour the interplay of education, research and industry/professional environment and to enhance food professional impact on society’ determinants and to contribute to the innovation and safety of the food chain towards a sustainable food supply chain at an international level.

Important exploitation outputs of the projects developed in the course by the ISEKI_Food network pillars of the IFA activities include:

- The International Journal of Food Studies (IJFS - http://www.iseki-food-ejournal.com/ojs/index.php/e-journal), international peer-reviewed open-access journal featuring scientific articles on the world of Food in Education, Research and Industry.

- The International ISEKI_Food conference (http://www.isekiconferences.com/) aimed to contribute to the creation of an "open" international forum for researchers, education scientists, technologists and industry representatives as well as food consumers, to promote a constructive dialogue and collaboration between Industry and Education on topics relevant to Food Science and Technology. The 4th ISEKI_Food Conference, held in 2016 in Vienna (AT) will be held under the theme “Responsible Research and Innovation in the Food Value Chain”.

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SESSION F: REGIONAL ASPECTS

F.1. THE USE OF BIOMASS FOR ENERGY PRODUCTION AND ORGANIC FERTILIZER FOR MITIGATING CLIMATE CHANGE AND IMPROVING THE COMPETITIVENESS OF THE AGRICULTURAL ENTERPRISE: THE CASE OF THE UPAP[1] EN PURISCAL, COSTA RICA[2]

Quirós Madrigal, Olman[3]
Arias Fallas, Lady[4]

Introduction

Agriculture is at a crossroads: produce food for a growing population but in turn should reduce their negative environmental impacts due to the emission of greenhouse gases that directly affect climate change facing the world community today . This also leads to the concern of agricultural producres: competitiveness. This challenge shows that "business as usual" (Guy, page 11) is no longer an option to face the challenges of the Millennium.

These impacts and adaptation needs are especially important for farmers in developing countries. Given this need UPAP, in the Canton of Puriscal, Costa Rica, has been making efforts to transform their company in order to adapt new technologies that allow them to reduce their production costs by reusing biomass (manure from cattle mainly) to generate energy and produce organic fertilizers are distributed among farmers affiliated to the Association. The UPAP's main economic activity is auctioning livestock (cattle bidding / auction), which generates a large amount of biomass (cattle excreta). This biomass must be transformed into other inputs in order to be recycled or reused. The goal is to improve competitiveness throughout the agri-food system in which different actors are involved: the UPAP Puriscal Canton and small farmers.

Considering the current laws (199th Zeledon, 199b), the UPAP requested support from MAG experts to plan and develop the "Project: Construction of a biodigester and production of vermicompost" that allows compliance with current management requirements "waste" of farming. The guiding question was to support the project: how to manage the biomass produced in the cattle auction to mitigate the negative externalities and also monetize the necessary investments?

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[1] UPAP: Puriscal Farmers Association (Unión de Pequeños Agricultores de Puriscal, Costa Rica).

[2] Project: "Red Iberoamericana de Bioeconomía y Cambio Climático". Coordinated Universidad Nacional Autónoma de Nuevo León, Nicaragua. Supported by "Porgrama Iberoamericano de Ciencia y Tecnología para el Desarrollo" (CYTED: http://www.cyted.org)

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Objective

The main objective is to identify and assess the impacts generated by the construction and operation of the biodigester and production of vermicompost on the farm of the UPAP, as an alternative method for treating manure from livestock on the stalls of the auction.

The specific objectives are:

a. To identify the environmental importance of recycling proposed, based on the construction of a biodigester and vermicompost treatment.

b. To conduct a preliminary economic analysis due the implementation of technologies identified in the project.

Methodology

The research was developed in phases, taking into consideration the importance of the issue and the need to organize information as a basis for disseminating proposals that allow agribusiness solve their negative impact to the environment while maintaining their competitiveness. The requirements that the laws of Health and Environment are defined to allow these agribusiness activities were also considered. The phases of the research were:

1. Jointly with experts from the Ministry of Agriculture and Livestock (MAG) of the Canton of Puriscal, UAPA was identified as a representative for the small and medium producers of Canton.

2. the laws regulating such activities were reviewed.

3. Conducted tour of the farm of UPAP and staff interviews of both the Association and the MAG.

4. Review of secondary information based on statistics UPAP marketing, sales, costs, revenues.

The different activities were carried out during the period December 2014 to April 2015[2]

Agribusiness description and main activity

The UPAP is an organization made up of small and medium farmers in the Canton of Puriscal and owns a farm in this Canton. The farm of 14 ha, its principal activity is the marketing of cattle in the region as a strategy to get the best prices for producers. This marketing is done through a "cattle auction Program" which is organized twice a week: Tuesdays and Thursdays. The activity begins with the reception of the animals on Mondays and Wednesdays, between the 4:00 pm to 8:00 pm, and even the day of the auction at the hours 6:00 a.m. to 10:00 a.m. The auction begins at 10 am and takes about 2-3 hours, with an average of 180 animals per transaction auction. This means that 360 animals are sold per week on average.

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[2] See bibliography consulted laws

Proposal for handling biomass

The biomass produced can be used for energy production or composting for use in agricultural production. At the same time the production of energy can be used directly as heat energy or can be used directly in the kitchen of houses or in their transformation into electrical energy for use in agribusiness activities and others. From the analysis of available information, and in discussion with experts from the MAG, was defined the use of biogas for cooking because the Restaurant which opes during the work days of the auction.

To produce the compost was primarily considered the cost of labor. Therefore making vermicompost with the use of the Californian red worm (*Eisenia foetida*) as the best alternative was identified. This activity allows the UPAP use underutilized infrastructure.

The biodigester

With the support of experts from the MAG (Guerrero 2015; Elizondo 2015) an assessment of the activity to specify the type of biodigester that was to be built was prepared. This diagnosis included: number of animals, time spent in each auction, amount of water and manure and recognition of facilities. The specifications of the type of biodigester showed: tubular with 19 m long and 2.5 m in diameter, allowing a capacity of 30 m^3. The material used is permaflex geomembrane Amanco[3] (PVC). Further notes that the approximate retention time (TDR) is a month to properly processed the manure and that when released it is a 85% free of contaminants (Guerrero 2015).

The process runs as follows:

Once the auction is over, the corrals are washed only with water, a process that takes about 6-7 hours with 2 workers. The material (manure) represents the raw material collected to feed the biodigester and to produce vermicompost. The manure is collected in an external collection tank, where it is stored and leads to 4 sedimentation tanks. External tank dimensions are 1.5 m by 4 m long and are filled an average of 10-12 times a week. When this is filled, the process of separating liquids with solids becomes. The solid manure is deposited in the sedimentation tanks for the production of vermicompost and liquid is conducted to the biodigester. The gas produced is for use in the Restaurant located at the headquarters of the UPAP, which runs on Tuesdays and Thursdays and in a house for the farm worker.

The vermicompost

The resulting solid material from 4 sedimentation tanks described above, allowed to dry "resting" for 8 days. When dry, this material is passed to the vermicompost process. On average is extracted 50-70 kg of organic material per week. In these tanks remain for six months and it sould be changed tank by

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[3] Trade mark

tank and in the last one is where the organic material is extracted for later packaging. In the first tank starts the process at ground level with 10 kilos of red worm and about 200 kg of the dry manure, and remains there two months and the worms are feeding every 10 days before to be passed to the next tank. After six months it reaches the 50% of the last tank where the dry manure, transformed now in organic fertilizer, is separated then from red worms. At the end of six months, the resulting compost or organic fertilizer is transported to a galerón where the drying process is completed and filled in bags of 20-25 kg. This last process takes 22 days on average and 60 bags are obtained. These are then sold at ₡ 4,000.00/ bag.

The preliminary results

The economic importance of biogas and vermicompost

To calculate the biogas production, was assumed that each animal produces an estimated of 13 kg manure per day and the biogas conversion from these manure is 0.03 (Gon 2008). Manure production by the 360 cattles are 2.283,42 kg/ day. However it should be take into account that the average length of animals are 2.5 days / week in the corrals. Therefore the ratio of 50% in the production of manure/week is accepted. Based on this ratio of the availability of manure production / week, was estimated the production of 85.62 m^3 biogas/ week.

From the objectives, the produced biogas must represent a saving for agribusiness, since energy is produced and reduces waste. Assuming that 1 m3 biogas (5.500Kcal / m3)replaced 0.60 m3 of natural gas (LPG) of 9300 Kcal / m3 of calorific. In the agribusiness-UPAP, the biogas consumption amounts reaches to 30.72 m^3 / week for use in livestock auction facilities and 26.88 m^3 / week for use in the worker's house for a total consumption of 57.60 m^3 / week.

Regarding to the economic value of the biogás, was calculated the approximate value of the savings due the replacement of liquefied petroleum gas (LPG) for biogas (GN) produced in the biodigester. Whereas 1kg of LPG equivalent to 1.28 m^3 of biogas and that the LPG market value is estimated at ₡ 708.33 kg, it is therefore the value of the biogas used is ₡ 127,499.40 / month.

Moreover, the income from organic fertilizer were estimated. Since every six months on average are sold 90 bags of 20 to 25 kilos, with a price of ₡ 4,000 per bag. The average value of this fertilizer is sold ₡ 60,000.00 / month. Therefore the total income amounted to ₡ 187,499.00 / month.

Additional the labor cost (2 workers) for the maintenance activities of the biodigester and vermicompost process requires a full-time worker and another part-time for washing (4 hours per week). The total cost of labor amounts to ₡ 137,280.00 / week for a total of ₡ 549,120 / month.

Cost / benefit ratio

The benefits to the biodigester and production of organic fertilizer project are represented by savings in the cost of electricity because the use of biogas and the compost (organic fertilizer) sales. The main cost is presented by labor because is essentially a fixed cost. It does not include here the cost of investing in the infrastructure of the biodigester as this is a preliminary analysis of gross profit. These preliminary results show a clear economic disadvantage investment in mitigating the negative externalities of agribusiness and showing a shortfall of ₡ 361,621 / month. The inefficiency in the use of biogas as well as the time to the production of vermicompost seem to be the most important factors that must be analyzed to make the project more efficient.

Conclusions and recommendations

1. It is important to consider that this is an initial study to evaluate the use of biogas and vermicompost and aims to collect and systematize information that demonstrate the economic and environmental viability of investments in technologies to reduce emissions of greenhouse gases and thus mitigating actions that cause climate change. More research is required under tropical conditions that allow developing appropriate technology and more efficient than that adopted by the UPAP-project.

2. Optimal use of biogas is not done, which affecting the results of the preliminary economic analysis. The efficient use of resources should be improved. In analyzing the relationship between the estimated biogas per week amounting to 85.65 m^3 / week and consumption barely reaches 57.60 m^3 / week amount, it becomes clear that there is significant under-utilization of the resource produced. It is also necessary to evaluate the process of production of organic fertilizer. Besides labor, which is a factor that also requires an analysis to improve efficiency due the cost to agribusiness.

3. There have not been analyzed in greater depth the socio-environmental benefits of investments for mitigation of greenhouse gases. It only was assessed reducing gases released into the environment. In addition to the use of biogas as an energy source can avoid the use of firewood. This has a significant environmental benefit if is consider that 1 m^3 of gas prevents deforestation of 0.33 ha of forest (MAG 2010).

4. It must make progress in further studies that include long-term investments such as infrastructure in general. Likewise, more research is required to make available new tools for economic and environmental analysis.

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F.2. BIOPIRACY OF TRADITIONAL KNOWLEDGE AND BIODIVERSITY FROM MEXICO?

Manuel Soria López and Israel Fuentes Páramo

1 Introduction

Mexico is a mega diverse country due to its extraordinary biological and cultural diversity. However, except for certain anecdotic or fragmented studies, indicators or sustained evidence on biopiracy of varieties and species from the Mexican territory are absent in the patent literature. Moreover, the occurrence of cases and evidence of biopiracy in the literature on bioeconomics is negligible, except for certain paradigmatic cases like the Neem Tree from India and the Maca from Peru. This essay proposes a method for generating quantitative and qualitative data on biopiracy through patent search and analysis. 'Biopiracy' is the illegal or improper extraction, appropriation and control of the elements of biodiversity –plants, fungi, animals, gens and other endemic biological materials, as well as of the traditional knowledge, from countries and regions of the indigenous, campesino and rural communities. 'Traditional knowledge' refers to ancient and contemporary wisdom and knowhow developed and learnt by indigenous, campesino and rural communities through their relationship with local biodiversity, transmitted orally by generations, shared and distributed in a fragmentary way and, of an holistic and spiritual character. The action of biopiracy is an element of the asymmetric and unequal exchange of knowledge, biodiversity and benefits between the developed and developing countries.

2 Methodology and materials

The method for identifying probable cases of biopiracy in patents was applied to six randomly selected endemic plants used in Mexican traditional medicine, which are the following: Santa María (*Tanacetum parthenium*), Tepezcohuite (*Mimosa tenuiflora*), Zoapatle (*Montanoa tomentosa*), Damiana (*Turnera diffusa*), Árnica Roja (*Galphimia Glauca*), Huizache (*Acacia farnesiana*). The method consists of two phases. First, it identifies a selected sample of patents as a set of possible cases of biopiracy. Then comes a second phase for the sustainment of specific cases of biopiracy.

The process for identifying biopiracy in patents begins, first, by selecting a specific group of plants – medicinal in this case, and then searching through patents using selected codifiers that represent particular aspects of these plants. For medicinal plants the codifiers have to do with the different names of a plant –common use and scientific, its basic components or substances and, the main medical uses of the plant. These are then searched for in the world´s main patent databases –USA, European Union and Japan, and looked for in certain sections of each patent document: title, abstract, description and claims. The result of this process is a set of patent documents as a sample in which, presumably, biopiracy could be occurring as a possibility yet to sustain.

Second, based on the results from the first step, comes the process of sustaining that a particular patent is part of an act of biopiracy. Sustaining this is much more complex than identifying it, because each case of biopiracy involves scientific, technological, institutional and economic aspects. In this step the central idea of the method is to contrast the traditional knowledge with technological knowledge in the patent –specially in sections as description and claims which constitute the discursive heart of the patent monopoly, by questioning the factors for granting a patent: disclosure, novelty, inventive step and industrial application.

3 Preliminary evidence on biopiracy in Mexico

Once applied, the described method rendered a total sample composed of 221 registered patents: 137 are granted patents and 84 patents were applications, all in which either of these plants, its components and/or medical uses appear in the referred sections of the patent.

3.1 Identifying biopiracy in patents

Priority data indicates that the larger part of these patents was registered for the first time in USA (50%), followed by the European Union (31%) or Japan (15%) and only a few in Mexico (4%). In terms of the country of origin of the assignees of this sample of patents most of them come from the USA (40%) and European Union (39%), followed by assignees from Japan (15%) and Mexicans (6%). According to the type of agent the evidence indicates that the major part of this sample are property of firms (73%), followed by individual inventors (22%) and finally by universities (5%).

The evidence illustrates that Santa Maria is the medicinal plant which reached the highest frequencies in terms of each codifier for names, components and medical uses (51%); the largest part of its share appeared in the Description (35%) and the rest in Claims (16%). The other five plants added up for the other half of the frequencies of the codifiers that appeared in these selected sections of the patents. The Tepezcohuite (17%), Zoapatle (12%) and Damiana (12%) obtained shares in a close range between them, while Árnica Roja (3%) and Huizache (6%) registered the lowest shares of all.

The differences in the results between these plants are even more notorious if each share of the 'claims' section –the discursive heart of the monopoly, is compared. For example, on one hand, while the Santa Maria reached the highest level of codifiers (15.5%), the Huizache registered the last place (1%) between the codifiers of the six selected plants. On the other hand, the medicinal plants as the Tepezcohuite (5%), Zoapatle (3%), Damiana (4%) and, Árnica Roja (2.5%) registered a relatively similar portions of the frequency, adding up for almost (14.5%) the same share as the Santa Maria.

In short, what the evidence from this sample of patents indicates is that the frequency reached by each codifier produces enough data input from each section of each selected patent as a potential case of biopiracy. Upon this data follows the process of selection of a series of pieces of ‘relevant text’ in terms of the controversy with traditional knowledge within the realms of the disclosure, novelty, creativity or industrial application of the patent.

Sustaining biopiracy in patents

After the identification comes the broad and complex task of analyzing each patent in particular in order to really sustain a case of biopiracy. The central idea is to localize “relevant texts” in the patent document that suggest biopiracy. The core of the technological knowledge disclosed in the patent’s description and claimed as novel, creative and industrially applicable, is to be confronted with the explicit and tacit traditional knowledge in the matter. A series of research questions arise in order to sustain biopiracy in patents:

In the background section of the patent document, the disclosure on the invention includes the place or people of origin of a certain traditional knowledge or plant contained in the patent?

The disclosure of the invention is clear and complete in a patent that involves biodiversity and/or traditional knowledge?

The patented invention has novelty and creativity compared to the codified and tacit traditional knowledge in the matter?

Which is the industrial scope of the monopoly over the country and community of origin of the plant and the traditional knowledge involved in the patent?

How does the patent monopoly affect the use and conservation of the plant *in situ* at the original localities?

Take for example the Tepezcohuite tree, localized in the geographic zone of the ancient Mayan culture (Southeast of Mexico and in Guatemala). In this case selected evidence indicates that the number of patents containing it have risen. During the period 1989-1999, only six patents containing it were granted and, by the period 2001-2012, twenty more patents containing Tepezcohuite were granted. The first series of patents that contained it, dated back to 1988-1992, were property of the individuals that invented them

–some alone and others in a groups of Mexicans and Foreigners. Nevertheless, since the end of the first period and during the second period, fourteen firms incorporated Tepezcohuite into their patents.

In short, the evidence from this sample indicates that in terms of the patent’s technological monopoly, different innovating agents – mainly foreign firms from developed countries, control specific aspects of endemic plants from Mexico which have been used over the centuries in Mexican traditional medicine. Likewise, individual inventors represent another outstanding segment in the ownership of these patents. In the discursive terrain of these documents the hypothesis that arises is that novelty was not completely demonstrated when compared to existing traditional knowledge and uses of the plant in its communities of origin.

4 Discussion and Conclusions

The main contribution of this paper to the discussion, since sound evidence on biopiracy isn't yet found in Mexico, are some ideas of how to tackle the problem of measuring biopiracy effectively, both in qualitative and quantitative terms. This essay contributes to discuss and develop a method for identifying and sustaining cases of biopiracy in patents which could be eventually useful for discovering asymmetric relationships between industrialized and developing countries when transferring knowledge, biodiversity and benefits.

The main finding from the evidence is –besides the fact that patents containing specific elements from Mexican biodiversity are increasing, that a few foreign assignees, mainly firms, own almost all of the patents of this sample that contain selected endemic plants used for centuries in Mexican traditional medicine by indigenous, campesino and rural communities. Due to their territorial and cultural origin and realm, the legitimacy and legality of the patents containing these plants has never been an issue of examination in Mexico, not even considering loss and conservation of its extraordinary dotation within the world's biodiversity and the cultural diversity of indigenous peoples.

This sample of patents constitutes possible cases of biopiracy that should be examined thoroughly and sustained considering scientific, technological and traditional knowledge systems as well as institutional, judicial and economical terms. The central idea is that once the core of technological knowledge disclosed in the patent's description and claimed as novel, creative ad industrially applicable is identified as possible biopiracy, then, it is to be confronted with explicit and tacit traditional knowledge in the matter.

As an experiment, what is the validity of the proposed method and the preliminary results?

The importance of these examples as probable cases of biopiracy in patents of traditional knowledge and endemic plants used in Mexican traditional medicine is that they represent one of the first and counted academic research attempts which begins to explore and discuss explicit cases of biopiracy. Further from this, of course, the effective sustainment of each case of biopiracy in judicial and institutional terms in Mexico remains as a task.

If the evidence on biopiracy can be generated, then, it will be useful as a direct indicator of the existence of an asymmetric relationship and an indirect indicator of the economic value of the traditional knowledge integrated to technological knowledge in the patent. Of course, even if proof is given of its existence, biopiracy doesn't necessarily stop. To do it legally is a complex task due to both the nature of biopiracy as well as of the judicial system under which each case is filled. However, as an indicator of potential market value in an asymmetric and unequal relationship, it also points out an opportunity to build agreements and contracts for sharing and transferring knowledge and biodiversity between the interested agents involved.