Environmental and Economic Life Cycle Inventory of Brussels Sprouts

Rubio-Sánchez M., San Miguel G.*

Affiliation and address: Universidad Politécnica de Madrid, Grupo de Agroenergética, ETSII, Department of Chemical and Environmental Engineering, c/ José Gutiérrez Abascal, 2, Madrid, 28006 (Spain), Tel.: (+34) 91 4524862

*corresponding author: g.sanmiguel@upm.es

Abstract

This investigation describes de material, energy and monetary inventories required to evaluate the environmental and economic performance of Brussel sprouts produced in Mexico and consumed in the USA. This data was supplied by a company operating in Mexico as a first step in the production of a LCA and LCC analysis according to ISO 14040-14044: 2006. The inventory covers the following stages in the life cycle of the product: seeding, soil preparation and conditioning, cultivation (fertilization, fumigation and irrigation), harvesting, processing, packaging, internal transport and distribution.

Keywords: Inventory, LCA, LCC, Brussel sprouts, sustainability, cabbage.

1. Introduction

Brussel sprouts are a type of cruciferous vegetable (*Brassica oleracea* var. Gemmifera) grown for its edible buds, rich in carbohydrates, proteins and essential micro-nutrients (mainly vitamin C and vitamin K) and minerals (mainly Mn, P and Fe). The increasing demand for this horticulture product around the world is promoting its exports from emerging economies with lower agriculture costs that play an important role in food security, to developed markets with higher paying capacities (FAO, 2018). In a sector increasingly concern with its sustainability performance, this investigation aims to bring light into the environmental and economic performance of Brussel sprouts produced in Mexico and consumed in the USA where they are usually exported (Cerutti et al., 2014).

The aim of this investigation is to identify and quantify the material, energy and monetary inputs associated with the production of Brussel sprouts in the form of a Life Cycle Inventory (LCI). This information may be used as the basis to assemble the Life Cycle Assessment (LCA) and a Life Cycle Cost (LCC) analysis of this product.

2. Materials and Methods

This preliminary LCI was carried out according to ISO 14040-4:2006 standards using as functional unit 1 kg of Brussel sprouts. Figure 1 describes the system under investigation, boundaries and flows (material, energy and monetary) considered. Specific inventory data was supplied by a commercial producer operating in Baja California (México). Generic inventory data were obtained from Ecoinvent v. 3.1 (Weidema et al., 2013) and Agri-footprint databases (Blonk, 2019).

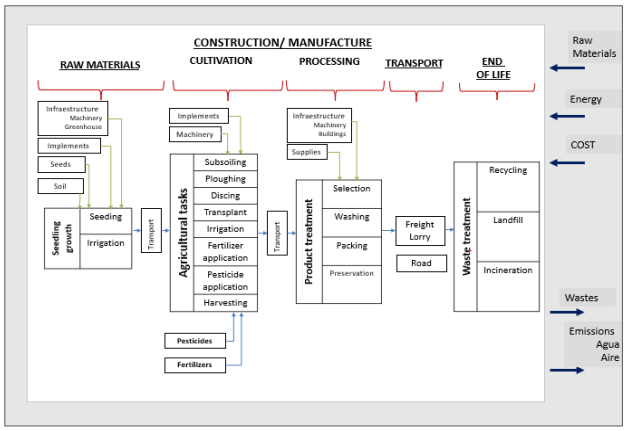

Figure 1. *Life cycle processes, system boundaries and flows considered in the LCI of the Brussels sprouts*

3. Results

The inventory shows that the main characteristic inputs associated with agricultural production are the use of water, energy, fertilizers and pesticides. Water consumptions is one of the main topics for LCIs. Most of the direct water use is attributable to irrigation practices, with a smaller contribution associated with the seeding and processing (washing) of the final product.

The use of fertilizers and pesticides is relevant issue in this investigation. The environmental performance of these products is related to both their fabrication and their application to the soil. Table 3 provides a complete inventory of these products, which are expected to have negative effect on impact categories related to toxicity and eutrophication.

According the producer, the cost of producing 1 kg of Brussel sprout is 0.85 $USD. A large proportion of this value is associated with the transportation of the final product from the production plot to the distributer in the USA. The cost of water use may be affected by subsidies applied in Latin-American countries like Mexico.

Table 1. *Inventory for the seeding stage per year (inputs per FU= 1kg broussel sprouts)*

Operation	Tools & Resources	Input	Units	Input	Units	$USD/FU
Planting	Greenhouse	2.00E+03	m2/ha	7.53E-02	m2/FU	1.24E-03
	Seeds	1.93E-03	kg/ha	7.27E-08	kg/FU	3.82E-04
	Vermiculite soil	51.75	kg/ha	1.95E-03	kg/FU	9.25E-07
	Perlite soil	51.75	kg/ha	1.95E-03	kg/FU	1.20E-09
	Polystyrene tray	1.93E+01	kg/ha	7.28E-04	kg/FU	4.33E-03
	Energy	3.43E+04	kWh/ha	1.29E+00	kWh/FU	2.21E-03
	Water	2.83E+00	m3/ha	1.06E-04	M3/FU	4.24E-07
Transport	Lorry	5.73E+02	tkm/ha	2.16E-02	tkm/FU	3.64E-02
	Diesel	3.11E+00	l/ha	1.17E-04	l/FU	1.07E-04

Table 2. *Inventory for cultivation phase per year (inputs per FU= 1kg broussel sprouts)*

Operation	Tools & Resources	Inputs	Units	Inputs	Units	$USD/FU
Soil prepar	Fuel consumption	4.40E+02	l/ha	1.16E+01	l/FU	1.04E-02
Discing	Disc	3.80E+01	ha	3.77E-05	ha/FU	1.26E-04
Subsoiling	Subsoil plow	3.80E+01	ha	3.77E-05	ha/FU	1.05E-04
Ploughing	Three-furrow plough	3.80E+01	ha	3.77E-05	ha/FU	7.90E-05
Irrigation	Energy	1.35E+02	kWh/ha	5.09E-03	kWh/FU	1.64E-04
	Water	8.00E+03	m3/ha	3.01E-01	m3/FU	5.30E-11
	Pump submersible	2.23E+04	m3h/ha	8.39E-01	m3h/FU	1.98E-03
	PVC tube	2.53E+02	kg/ha	9.52E-03	kg/FU	2.78E-06
	Drip tape	1.58E+00	kg/ha	5.95E-05	kg/FU	1.13E-04
Harvesting	Recycled PE box	4.01E+04	kg/ha	1.51E+00	kg/FU	4.41E-02
Transport	Freight Lorry	5.91E+05	tkm/ha	2.23E+01	tkm/FU	3.12E-01

Table 3. *Inventory for fertilzation and fumigation phase per year (inputs per FU= 1kg broussel sprouts)*

Operation	Commercial name	Active ingredient	Input	
			kg	$USD
Fumigation	Meta Qo	Methamidophos	7.53E-05	8.81E-04
	Fijator 70CE	*Lambda Cyhalotrina*	5.65E-05	1.14E-03
	Decker 400CE	Dimethoate	7.53E-05	7.21E-04
	Sifagard	Permethrin	7.53E-05	1.28E-03
	Bio BT	*Bacillus thuringiensis*	3.01E-04	1.07E-02
	Buffer XS	Acidifier	6.03E-04	3.84E-03
	Ventas 480	Chlorpyrifos Etid	1.13E-04	7.21E-03
	Orthcne Ultra	Acefate	7.53E-05	8.81E-04
	ProAxis	*Gamma Cyhalotrina*	5.65E-05	1.95E-03
	Mos Blanc 350	Imidacloprid	1.50E-05	1.11E-03
	Prochaimoras	Benzoate	2.39E-05	4.00E-03
	Radiant	Emamectin Spinosad	2.64E-05	2.76E-03
Fertilization	Quimical	Ammonium nitrate	7.53E-03	3.65E-02
	Yara	Calcium nitrate	1.02E-02	5.81E-03
	Hifa	Triple 20-20-20	3.01E-03	7.57E-03
	Yara	Potassium nitrate	6.78E-03	7.85E-03
	Dune CO	Phosphoric acid	2.27E-02	2.21E-01

Table 4. Inventory for processing phase per year (inputs per FU= 1kg broussel sprouts)

Operation	Tools & Resources	Input values	Units	Input values	Units	$USD/UF
Energy		6.08E+03	kWh/ha	2.29E-01	kWh/UF	7.38E-03
Selection	Conveyor belts	3.16E+01	kg/ha	1.19E-03	kg/UF	1.49E-02
Washing	Washing system	2.05E+01	kg/ha	7.73E-04	kg/UF	2.78E-04
	Water	1.19E-06	m3/ha	4.48E-11	m3/UF	7.87E-21
	Citric acid	6.32E-03	l/ha	2.38E-07	l/UF	9.10E-07
	Chlorine	9.47E-03	l/ha	3.57E-07	l/UF	2.93E-07
Preservation	Conserv. chamber	5.53E+02	kg·día/ha	2.08E-02	kg·día/UF	2.78E-02
Packing	PPC boxes	1.05E+03	kg/ha	3.97E-02	kg/UF	8.82E-01
	Wood pallets	2.73E+02	kg/ha	1.03E-02	kg/UF	1.18E-03
Transport	Freight Lorry	1.60E+06	tkm/ha	6.02E+01	tkm/UF	4.12E-01

4. Conclusion

This investigation provides a preliminary LCI of Brussel sprouts produced in Baja California (Mexico) and consumed in the USA. The data includes seeding, soil preparation and conditioning, cultivation (fertilization, fumigation and irrigation), harvesting, processing, packaging, internal transport and distribution. Subsequent work related to this investigation will include: definition of production and transport scenarios, definition of end of life scenarios for packaging and food products, evaluation of the fate of fertilizers and pesticides, expansion of inventories related to processing of final products, collections of uncertainty data and construction of LCA and LCC models.

References

Blonc Consultants (2019) Agri-footprint, LCA database, www.agri-footprint.com

Cerutti, A. K., Beccaro, G. L., Bruun, S., Bosco, S., Donno, D., Notarnicola, B. and Bounous, G. (2014) Life cycle assessment application in the fruit sector : State of the art and recommendations for environmental declarations of fruit products, Journal of Cleaner Production, 73, 125–135

FAO (2018) FAOSTAT Database Food and Agriculture Organization of the United Nations. Rome, Italy. FAO. Retrieved. 2018, www.fao.org/faostat/es/#compar

Weidema, B.P., Bauer. C., Hischier, R., Mutel, C., Nemecek, T., Reinhard, J., Vadenbo, C.O., Wernet, G., 2013. Overview and methodology. Data quality guideline for the ecoinvent database version 3. Ecoinvent Report 1(v3). St. Gallen: The Ecoinvent Centre.